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J. W. RICHARDS, PH.D.....*President*
E. F. ROEBER, PH.D.....*Editor and Secretary*
C. E. WHITTLESEY.....*Treasurer*

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Electrode Troubles and Electrode Losses.

The demand for furnace electrodes has been aptly called a barometer of electrometallurgical activity. From the present indications of this barometer the near future of the electrometallurgical industry looks exceedingly bright. On the other hand, electrodes represent just at present the chief trouble of electric furnace designers and operators. With the increase in the size of furnaces, there has arisen, with comparative suddenness, a demand for very large electrodes, but the baking of the largest sizes of amorphous carbon electrodes, so as to procure the same strength and durability as for the smaller sizes, seems still to involve some difficulties. In one very prominent case recourse has recently been had to graphite electrodes, which, while more expensive, are strong and durable and easily machined, there being no waste of electrode ends, as a new electrode is easily screwed into the end of an old one. After all, the first requisite is mechanical strength of the electrode; as described at the end of Mr. Hansen's interesting article in our present issue, the breakage of electrodes may cause very considerable trouble. In one case we know of, the trouble was enough to make an opening for the induction furnace. But as Mr. Hansen points out, there is nothing inherent in the nature of carbon that makes perfect electrodes impossible; and it is safe to say that the manufacture of large and perfect amorphous carbon electrodes in this country is only a question of time. Then there is the consumption of the electrodes by oxidation; this depends, to a considerable extent, at least, on the conditions of operation. Mr. Hansen's article gives some interesting data on this item. Finally, we have to consider the heat losses through the electrodes, which may form in many cases an important item in the heat balance sheet of the furnace.

* * *

Valuable experimental results on the heat losses through the electrodes were given by Mr. Hansen in former papers, while the results of a theoretical investigation of the same subject are given in a very interesting article by Mr. Hering in this issue. While Mr. Hering's article gives only general results, but not the methods and formulas of his analysis, we are glad to say that the latter will be given in full in two articles which Mr. Hering has promised us for our next two issues. For this reason we refrain for the present from a discussion of this subject, but wish to emphasize that in our opinion a purely theoretical investigation of such matters is exceedingly valuable and its importance should not be underrated. Even if such an analysis can be only approximate, it will give certain indications as to the lines along which experimental work should be carried out. Progress is generally made along such lines that we first make abstractions and establish a law which contains certain constants; then we make experiments and establish the discrepancies of the facts from our law and the way how our "constants" change. This gives a new law, and so on. The excellent work done by Mr. Hering and Mr. Hansen along theoretical and experimental lines will give us exact rules on

the dimensioning of electrodes. We are evidently now quickly approaching the time when electric furnace design will be as exact a science as dynamo-electric machinery design has been for many years.

* * *

Mr. Hering's article refers to the dimensioning of electrodes for continuous operation of the furnace. It will not be out of place to call attention to the fact that it may be necessary to employ other rules for the dimensioning of electrodes in such cases where a furnace is often started and stopped. Here the time element of starting becomes important. At present it seems that for quickly starting a furnace, the induction furnace has distinct advantages. Concerning the speed with which energy can be pumped into an induction furnace, interesting data were given in an article by Mr. FitzGerald on page 10 of our January issue.

Special Steels.

Professor Burgess' invention, made a few years ago, of a practical method of producing a very pure, carbon-free iron by electrolytic refining, has opened great possibilities for the industry of special steels. Our whole old metallurgy of steel has been restricted essentially to carbon-steels. Starting with electrolytic iron, Professor Burgess and his co-operators at the University of Wisconsin, have been able to prepare non-carbon steels containing various elements, and with assistance from the Carnegie Institution they have carried out an extensive study of the mechanical, electrical and magnetic properties of these steels. This is virtually a virgin field, with unlimited possibilities. We are glad to announce that the results so far obtained by Professor Burgess will be published in a series of articles in this journal. The first article will be found in this issue. The results obtained by Messrs. Burgess and Aston on the influence of arsenic and tin upon the magnetic properties of iron are both interesting and suggestive.

Refractories.

Since Peclet made his determinations of the heat conductivities of various materials, very little has been done by other experimenters to supply us with exact figures of the heat conductivities of the principal materials employed in furnace construction. This is really a remarkable state of affairs, in view of the absolute necessity of using these constants in the heat balance sheet of metallurgical furnaces. Further progress in metallurgy will depend essentially on hearty co-operation between theory and practice, by basing all practical designs of apparatus and processes on exact principles. But in order to do that, nothing is more needed than exact figures of the important physical constants of the various materials used in practice. For this reason we believe that the article by Wologdine and Queneau, the first part of which is published in this issue, forms a very important contribution to general metallurgy, in spite of its obvious shortcomings with respect to the temperature range treated. The part published in this issue deals with the conductivities of a large number of refractory materials, while the concluding installment, to be published in our next issue, will deal with their porosity and gas permeability. Our universities could do nothing more useful for chemical and metallurgical engineering than to establish researches along similar lines.

The Swing of the Pendulum.

Several analogies are conceivable between the laws of mathematical physics and those of political economy. One of the most general phenomena of the physical world is that of periodic vibrations—we see them in sound, in electromagnetism and, in fact, anywhere. A similar cyclic process is seen in trade. There is a period of quiescence, then a betterment of business, increased confidence, a new era of prosperity, excitement, over-speculation, a panic, liquidation, retrenchment, finally a period of quiescence again. This is the cycle of industry. We have seen the long swing of the pendulum and we have seen its short swing. Some writers are even quantitative in their reading of the past. Thus, they say: The country had the great panics of 1833, 1853, 1873, and 1893, and of 1837, 1857, 1877 and 1907 showing a periodicity of 20 years except when trade skips a beat, like the heart of an invalid, and the secondary panics having a period of 10 years. Whatever degree of accuracy be ascribed to this theory, it is undoubtedly true that business alternates between extreme industrial energizing and extreme industrial restriction in periods of 10 years or even multiples thereof, and that the years ending in '3 or in '7 mark usually the crisis.

* * *

Hard times are basically caused by the integrated extravagance of the nation. When everybody is making money and seeing his income increase, the temptation to spend is great. When much is spent on luxuries, which do not bring any great return in satisfaction, the demand for all labor and supplies is increased. As the old law of supply and demand works 24 hours a day, 365 days a year, the prices for all commodities and for all classes of labor increase with this increased demand. As the prices of all commodities are increased, the purchasing power or economic effectiveness of a dollar is decreased. As its effectiveness is decreased, its real earning power is decreased. On the other hand, due to the demand for capital, the interest rates are increased in the gradually increasing commercial activity. Hence the entrepreneur class, who borrow money to make it earn more than the rates of interest, are each year basically in a less and less favorable condition, although apparently they are each year of expanding business in a more and more favorable condition. Finally, the state of affairs grows worse until business must react, because the marginal profit for the entrepreneur has reached zero as its limit. For the interest rates have risen and the depreciated dollar will earn less than the interest asked on the ideal national average. Finally, a panic is started by some act like a "run" on a financial institution. Then a period of acute forced liquidation starts in the financial world and is transmitted to the manufacturing and distributing worlds. Outside conditions affect the cycle of prosperity and adversity both in its period and in its amplitude. For instance, the increase in the supply of gold increases the reserves and sustains the inflation. Fortuitous events, like earthquakes, great fires or wars between nations. "consume and destroy" and unhealthily stimulate trade. Unwise and paternalistic legislation destroys credit rapidly. The application of the principles and facts of science to everyday life and all industry increase the usufruct of the dollar and healthily stimulate trade.

* * *

But, after all, the average human mind changes very little

and it is especially prone to exaggerate both its hopes and its fears. And these errors are in the main the causes of commercial alternations. If each person would regulate his expenditures with a perfection of economic foresight, production and consumption would increase with the expansion of civilization at a small uniform rate and the practical effect would be a calm and steady progress. In short, the commercial impulses would be "commutated" and we would have a "direct current" and not an "alternating current." We have seen one bad panic and its subsequent period of liquidation, commercial house-cleaning and national economizing. The country after several years of high living is having a couple of years of saner living. The panic of 1907 gathered slowly, but its start was precipitated like almost every other serious panic by an incident that profoundly excited the fears of the capitalistic class. When fears as to the safety of the institution of credit are generated they proceed to the distributing and manufacturing classes. Each company, and, broadly speaking, each individual is both a producer and a consumer. If each consumer curtails his purchases even by a small amount he affects some other producer. And as each concern finds the market for its goods restricted, it starts in to retrench in its purchases. The same things occur with each individual. In this way the numberless chains of producer-consumer consumer-producer transmit the shock, which proceeds like a nervous chill through the commercial body. Finally the recuperative forces begin to have their effect. Labor, which was once dictatorial and inefficient, becomes now willing and efficient. The promoter, and especially the reckless promoter, has his schemes tested most carefully for their merits. Free capital piles up in the money centers and thus interest rates fall to such a rate that the margin for the entrepreneur, which previously to the panic had shrunk to zero, is now at a maximum. Improved processes and new machinery of certain and demonstrated value are installed. Finally, industry revives, at first slowly, then at an increasing rate. The circuits of producer-consumer and consumer-producer send out pulsations of nervous vigor and optimism. In fact, the nation's business no longer suffers from nervous prostration. Whereas the mouse would not gnaw the rope, the rope would not hang the man, and so on through the long series of causations till the pig refused to jump over the stile, the mouse starts to bite vigorously the rope, and the rope to hang the man, etc., till the stick begins to beat the dog and the dog to bite the little white pig, and the latter, with his old feminine owner, both get safely home. In an exactly analogous manner do the wheels of industry start turning each other.

* * *

All panics resemble each other somewhat, and each individual panic resembles a certain other panic specifically. Thus, the panic of 1893 resembled the panic of 1873 in the fact that legislation affecting the currency system in the United States did much to precipitate both. The panic of 1907 resembled even more strikingly the panic of 1857. As the last report of the New York Chamber of Commerce points out, there were in the years preceding both 1857 and 1907 the same immense increase in gold production and the same consequent inflation of prices, and the same increase in interest rates. There had also been the same extension of credits and the same waste of capital in unproductive works. Likewise, there had been the same great outlay in gigantic enterprises, the returns from which were delayed for years. Prior to 1857 had been the Crimean war. Prior to 1907, the Russia-Japanese war. The report also points the recovery as follows: "The year 1858 had been distinguished in the annals of commerce as one of the most important of the nineteenth century; distinguished alike for great fluctuation in market values, for a rapid recovery from the effects of the revulsion of the year 1857, and for the development of commercial enterprise at home and abroad." In 1858 "the process of recovery from depression involved a great falling off in the imports and the liberation of a large amount of capital from active employment. The money market became, therefore, flooded with money, and this reduced the rate of interest to a very low point." Precisely the same course has been seen in the year 1908. Imports decreased nearly $200,000,000 for the entire country, and over $100,000,000 for the port of New York. At the close of the year 1908 the money markets of the world were filled to overflowing with money seeking investment in sound securities. Whereas in January, 1908, the Bank of England's discount rate was 7 per cent, it had fallen at the close of the year to 2½ per cent.

* * *

The year 1908 shows the further analogy that the recovery started strongly because in both 1857 and 1907 the business of the country was inherently sound. Great enterprises, like the St. Paul extension to the Pacific Coast, the Gary Steel Works in Indiana, were well planned. Their final execution was at a reduced cost because of better conditions in the labor market and lower cost of supplies. The large copper reduction works in Utah and Nevada working on "monzonite" low-grade ores were designed for a maximum efficiency over a long period of years. All this vast aggregate of capital was tied up in 1907 in an unproductive form in the above-mentioned and similar enterprises. It is now giving handsome returns on the original investment. The year 1909 is showing, for many reasons, a healthy recovery over 1908. This is clearly indicated by the returns from the railroads, and especially by the increased iron production. Tariff agitation and the usual uncertainty about crops are brakes on the upward trend. Undoubtedly the greatest bear cards on the world's industrial horizon are the ill-advised socialistic legislation by the British House of Commons and the rivalry of the nations in building monster battleships. On the other hand, money is plentiful and interest rates low. Our industrial enterprises are managed each year with a higher degree of financial wisdom, commercial sagacity, and technical skill. National and individual extravagance will be always prevalent in a young, growing country. The labor question we will always have with us. And it will always manifest a disturbing influence in good times when the demand for labor is great. In general business, there seems to be a settled feeling that industry should be governed by a tempered and conservative enthusiasm rather than by an unlicensed exuberance. Unfortunately when prosperity is again in full swing, many will neglect conservatism and steer for charybdis in an ultra-optimistic spirit. For the old pendulum of trade swings pretty regularly between the excess of inflation and the excess of restriction, since its swings are caused by the vagaries of the average human mind. And the human mind changes but little as the years roll along.

The Iron and Steel Market.

As regards strictly new business, August has not been as active a month in the iron and steel trade as was July, while that month had fallen below June. In the case of both July and August the new business booked exceeded expectations, these expectations having been very moderate on account of there having been such heavy buying during the second quarter and by reason of July and August being normally very quiet months in the trade.

New buying by the railroads, however, has been very good, with the important exceptions of fabricated material and rails. Orders for steel cars and for locomotives have been increasing, while orders for car and track repair material have been very good. The consumption of tie plates this year is particularly good. Recently one of the several producers of tie plates, the Illinois Steel Company, reported that it had booked this year orders for 40,000 tons, while an order for 15,000 tons from the Harriman lines was pending. The present appearance is that the answer to the requirement for a better track support is the treated tie and tie plate, rather than the all-steel tie. The latter has of late made little progress into favor.

While it is improbable that the railroads will soon reach the rate of iron and steel consumption shown in 1906 and 1907, improvement is clearly being made. Outside the railroads, some lines of consumption have already shown a better tonnage than in either 1906 and 1907, and it is quite possible that within a twelvemonth this increase will be sufficient to bring the total tonnage to a new record rate, without the railroads doing as well as they did at their best.

The rail mills have opened their books for 1910 deliveries, and have made reservations of a considerable tonnage. In the spring there were some prospects that for 1910 the standard price of rails would be reduced, the prospects of tonnage for 1909 not having furnished any incentive for making an earlier reduction. The question of making any reduction has been finally dismissed, partly by reason of the general improvement in trade and partly through matters arising from the desire of the railroads for rails of better quality. The negotiating now is as to quality at the standard price, and as to extras to be charged for still better quality. The strategic position of the railroads is improved by the change, since it is easier to obtain concessions along the lines of better quality than along lines of a reduction in the base price.

Specifications on contracts for finished steel made in the second quarter have continued excellent, and mill operations have continued to increase.

Pig iron production has continued to increase, July showing a rate of 25,000,000 tons a year of coke, anthracite and charcoal, while August shows a still better rate. An increase in midsummer is altogether exceptional, as the output of a given furnace invariably decreases on account of the humidity. The increase in total production has occurred through the blowing-in of many additional furnaces, and prospects are that furnaces now operating will make a much larger output in October. It is not possible that October will make a new rate in pig iron production for the country, the previous record having been 28,000,000 tons a year, made in October, 1907.

The United States Steel Corporation, in July, made a new record for pig iron production, although not employing its full capacity, which has been largely increased since 1907. The independents ran practically full, and the fact that a new record for the country was not made was due largely to the fact that the merchant furnaces have not increased output as rapidly as the steel works furnaces. The product of the steel works furnaces has been going immediately into consumption and stocks at steel works have been reduced.

The labor disturbances which started in July have not all been settled. The Pressed Steel Car Company's strike is being stubbornly continued by the men, while the Amalgamated Association members have not yielded to the open-shop requirements of the American Sheet & Tin Plate Company. The company, however, has made some little progress toward breaking the deadlock, and is operating some of the mills in question with non-union labor. As to tin plate, the dull season has been reached and the requirements are not much heavier than the output of the 90 mills of the company, which have been regularly non-union.

Pig Iron.

Pig iron advanced slightly in the Central West early in August, while throughout the month the Eastern and Southern markets have showed an advancing tendency. In the East it is computed that foundry iron is within about 50 cents of the importing point, but experience in past movements has shown that the attainment of the theoretical balance does not invite imports because consumers do not care to change their brands except for a decided advantage in price. In 1907 there were times when imported iron, on dock, Philadelphia, was quoted $2 a ton under domestic iron. The tendency, however, is to arrest the advance in the East, while there are some indications that in the Central West the advance has already been arrested by furnace conditions. Additional furnaces are being blown in, while there are still some stocks of importance, and many consumers appear to be fully covered for the year. One evidence of this is that considerable inquiry has appeared for first quarter and first half delivery. In the fore part of August Bessemer pig iron advanced sharply to $16, valley, or $16.90, Pittsburgh, and sales were made, about 15,000 tons each, to the Republic Iron & Steel Company and the Youngstown Sheet & Tube Company. The market stands firm at this price. Basic and No. 2 foundry advanced to $15.25, valley, or $16.15, Pittsburgh, the market being firm at that price, with a tendency to ask high prices for fourth quarter or next year's delivery. Forge stands at $14.25, valley, and malleable at $15.50, valley.

Billets and Sheet Bars.

Billets and sheet bars have become very scarce, billets being quoted at an advance of a dollar a ton from July, at $24 for Bessemer and $25 to $26 for open-hearth, while sheet bars are $25.50 for random lengths and $26 for cut bars. These prices are at mill, Pittsburgh, plus full freight to destination. The advance in the general market has been greater than appears from a comparison of Pittsburgh prices, since formerly a portion of the freight from Pittsburgh was conceded in naming delivered prices. Forging billets are $1 higher at Pittsburgh, being quotable at $28. Rods are $31, Pittsburgh, since the $2 advance at the close of July.

Finished Materials.

Finished steel products have continued their advancing tendency. Steel bars have gradually advanced until the minimum is $1.35, Pittsburgh, an advance of $2 a ton in a month. Iron bars have moved upward, partly in sympathy with steel bars and partly on account of the stronger scrap market, and are quotable at $1.50, Pittsburgh. Plates and shapes have definitely advanced a dollar a ton, being quotable at $1.40 to $1.45, small orders regularly commanding the higher figure. By the advance of July 26 all wire products were advanced $2 a net ton, making nails $1.80. There is still a great deal of business being filled at the old price of $1.60, which ruled May 1 to May 15. A fair amount of business was taken at the advance of May 15, while very little tonnage has been booked at the advanced prices of July 28. It is definitely understood that while the leading interest will make no advance in tin plate for this year's delivery, it will not book orders for next year at less than $3.55, or 15 cents advance over the price ruling since last March. The market is quotable as follows, f.o.b., Pittsburgh:

Steel bars, $1.35, base.
Iron bars, $1.50, base.
Plates, $1.40 to $1.45.
Shapes, $1.40 to $1.45.

Standard rails, $28 for Bessemer and $30 for open-hearth, f.o.b. mill; light rails, 25 lb. to 45 lb., $26.50 to $27.50.

Sheets, 28 gauge, black, $2.20; galvanized, $3.25.

Tin plates, $3.40 for 100-lb. cokes.

Merchant steel pipe, ¼ in. to 6 in., inclusive, nominally 80 per cent off in "jobbers' carloads"; actual inside price, 81 and 5 off.

Plain wire, $1.60, base; wire nails, $1.80, base; painted barb wire, $1.80; galvanized barb wire, $2.10.

Electrometallurgy in Mexico.

The Mexican Steel & Chemical Company, organized under the laws of the Republic of Mexico, has been formed for the purpose of manufacturing different varieties of steel, calcium carbide and certain chemicals in the Republic.

The company will use the Héroult type of electric furnace for the manufacture of tool and drill steel, shoes and dies, forgings and steel castings, and it will also make light steel rails, 14 lb., 16 lb., 18 lb. and 20 lb. The rail plant will have a capacity of 20,000 tons of rails per annum to begin with, and the capacity of the electric steel furnace will be 16 tons to 20 tons per day of steel ingots.

These ingots will be worked up under the hammer into the different forms of tool and drill steel, shoes and dies, car axles, etc.

The company has also ordered, and is now constructing a plant for the manufacture of calcium carbide at the City of Mexico, using a continuous type of furnace.

The plant will have a capacity of from 3000 tons to 5000 tons of carbide per year, which will be sold in the Republic for purposes of acetylene lighting. Electric current will be furnished by the Mexican Light & Power Company, and will be taken from its mains at about 20,000 volts pressure.

Both the carbide furnace and the steel furnace will be of the single-phase type.

The company also expects to manufacture certain chemicals in a large way later on.

The carbide furnace should be in operation in about six months, and the steel plant some months later.

The company has purchased a tract of land of about 30 acres within the city limits of Mexico, where the work of construction is now going on.

Mr. Robert Turnbull, St. Catharines, Ont., Canada, acting for Dr. Héroult, will design and construct the steel furnace, while the carbide furnace will be designed and constructed by Mr. Charles Bingham, of 11 Queen Victoria Street, London.

Mr. J. T. Morrow, 25 Broad Street, New York City, is the managing director of the company.

Calcium Carbide Suits.

Judgment has just been rendered in two suits of the Union Carbide Co. versus the American Carbide Co. before the United States Circuit Court, Northern District of New York.

The first suit was based on the product patent 541,138 of Thomas L. Willson of June 18, 1895. The Union Carbide Co., as owner of this patent, charged the American Carbide Co. with infringement. Mr. Louis C. Raegener was counsel for the complainant, Messrs. Kernan & Kernan, with Mr. Charles Neavs and Mr. Willis Fowler were counsel for the defendant. The judgment is in favor of the defendant; the patent is upheld as valid, but no infringement is found.

The decision is rendered by Judge Ray. The principal claim of the patent refers to "a new product crystalline calcium carbide, existing as masses of aggregated crystals." We take from Judge Ray's decision the following extracts: "It seems to me plain on the face of the patent in connection with the file wrappers of his previous applications, that during the prior preceedings in the Patent Office, resulting in the final rejection of the claim for calcium carbide broadly, Willson had become informed that crystalline calcium carbide existed and was known prior to the date of his invention, and that after the rejection of his claims, he made up his mind that he had discovered, produced and invented 'a new form' of crystalline calcium carbide, one having a peculiar iridescence and existing as masses of aggregated crystals . . ."

Reference is made to an article by Moissan, of November, 1899, and Judge Ray says: "It is apparent from this and other publications and evidence that calcium carbide had been produced by the electric current in a suitable furnace as early as 1899, by others."

It is then pointed out that there are two forms of crystalline calcium carbide, first that existing in the form of crystal aggregates, or what is the same thing as aggregated crystals, and this may be in masses, and second, that existing in the form of crystalline aggregates. Judge Ray says: "I am of the opinion and hold under the weight of evidence that crystalline calcium carbide as Willson understod it, exists in at least two forms—not referring to the amorphous condition which is not crystalline in any sense, but the opposite." Messrs. Whitlock, Doremus, and Crocker, witnesses for the defendant, are quoted in this respect.

"I think the patent valid for what it claims, viz., crystalline calcium carbide existing as masses of aggregated crystals. I think this is a new form of calcium carbide produced by the use of lime in the presence of carbon heated, etc., in a socalled electric arc furnace, and that it is a form of calcium carbide which discloses such progress in the art as to make the patent valid. I think that by the process used by Willson he discovered a new and better form of crystalline calcium carbide, a new subdivision of it." . . .

"It is not sufficient for the complainant to show that defendant produces the commercial or chemical equivalent of complainant's crystalline calcium carbide existing as masses of aggregated crystals. The patent is for a particular form, a new form, and that form must be produced by defendant to constitute infringement."

Prof. Doremus is quoted as having examined defendant's calcium carbide and found it not to be crystalline calcium carbide, existing as masses of aggregate crystals, within the definition of the latter.

Judge Ray finally concludes: "It was neccessary for complainant to show, by admission, or otherwise, that defendant's product is calcium carbide; that it is crystalline and that its crystallinity consists in the fact that it, the carbide, exists as masses of aggregated crystals. To determine whether or not it so exists we must turn to the dictionaries and scientific works and writings of the time when this discovery was made and ascertain what the words used in the claim then meant, if they meant anything. This is what defendant's experts have done and this is what the Court has endeavored to do. Infringement must be proved by the complainant by a fair preponderance of evidence. Satisfied that infringement of this narrow claim is not made out, there will be a decree dismissing the bill with costs."

* * *

The second suit was based on the process patent of Willson, 563,527, of July 7, 1896. Messrs. Dickerson, Brown, Raegener and Matty, with S. L. Moody, were counsel for the Union Carbide Co. as complainant, while Messrs. Kernan & Kernan with Charles Neavs and Willis Fowler represented the American Carbide Co. as defendant. As this patent had expired since suit was brought, the decree could have been no injunction, but an accounting only. For this reason this suit was of less importance. But it is interesting as an endeavor is made to give a legal distinction between an arc and a resistance furnace. In the principal claim of this patent Willson speaks of "subjecting mingled lime of a carbonaceous deoxodising agent to the heat of an electric arc in an electric furnace . . ." Willson's patent refers therefore to an arc furnace.

Judge Ray reaches the following conclusions: "I think the

evidence establishes, 1, that the material used by the defendant in his mixture, or some of it, acts as a conductor and is not a gaseous vapor; 2, that some of this material offering resistance and being of low conductivity becomes intensely heated to incandescence; 3, that in addition, because of the imperfect union of this conducting material, innumerable small arcs are formed which aid in giving the heat; 4, that there is no single arc in the defendant's process, except at the very beginning and when the current is being established, and that this is very soon extinguished when the material is fed in filling the space between the electrodes and extending up around the carbon pencils, forming the upper electrode; 5, that the reducing of the material fed in and intended to be reduced is done mainly, but not wholly, by incandescence, for the reasons stated. Finally, I think it shown by the preponderance of evidence that defendants' furnace, on the whole, acts on the incandescent principle, and not on the arc principle, and must be termed an incandescence furnace, and, therefore, is not within or covered by the limited claim in issue of the patent in suit. It follows that the defendant does not infringe, and the bill of complaint must be dismissed with costs."

* * *

The above descisions, rendered by the United States Circuit Court of the Northern District of New York, are the first decisions rendered in the calcium carbide litigation in this country.

It is understood that the Union Carbide Company has appealed to the Court of Appeals.

German Foundrymen's Association.

A German Foundrymen's Association (Verein Deutscher Giessereifachlente) has just been formed in Berlin for the furtherance of foundry practice and science. The offices of the association are at 60 Sybel Strasse, Charlottenburg.

Institute of Metals.

During the first year of its existence the membership of the (British) Institute of Metals has increased from 200 to well over 500. The first volume of the *Journal* of the institute has been issued, and was reviewed in our August issue, page 374.

The autumn meeting of the Institute will be held in Manchester on Oct. 14 and 15.

We learn that when Sir William White, K.C.B., F.R.S., retires from the presidency of the Institute of Metals at the end of the present year, it is almost certain that Sir Gerard Muntz, Bart., will be nominated to the vacant office. The vacancy in the vice-presidency caused by the recent death of Mr. Norman Cookson, of Newcastle-on-Tyne, has been filled by the council, which, at a recent meeting, unanimously elected Dr. H. C. H. Carpenter, of Manchester.

Faraday Society.

The forty-fifth ordinary meeting of the (British) Faraday Society was held in London on June 15, Dr. N. T. M. Wilsmore occupying the chair.

Mr. E. R. Taylor, of Penn Yan, N. Y., presented a paper on "the national and international **conservation of water for power.**" In substance it was the same as his paper before the International Congress for Applied Chemistry, abstracted in our July issue.

In the discussion which followed, Mr. Walter Reid pointed out that the conservation of water-power over large areas might be very difficult of accomplishment in England, where the value of land was so high, and where there was a large number of cities very close together. Moreover, the question of scenery, which was a national possession, had frequently to be taken into consideration. The Government had, however, recently promised, through the president of the Local Government Board, to take action with regard to the conservation of all British rivers, each of which was to be placed under the control of one central authority.

Mr. W. Murray Morrison showed how nothing but good had followed the development of the power schemes at Foyers and Loch Leven, now the centers of a flourishing industry and population. There were many such possible centers of power, especially in Scotland. Water-power was one of the most formidable weapons with which a nation had to fight the modern war of industry.

Dr. H. Born emphasized the importance of bringing home to the nation the value of the small water-power.

The chairman remarked on the way in which the land was entirely utilized in Germany, where 20 per cent of the land was forest, and no part, as far as he knew, was given over to waste.

Mr. W. Fielding then read a paper on "the formation of silicon sulphide in the **desulphurization of iron.**" This paper was published in our last issue, page 347.

In the discussion which followed, Prof. A. K. Huntington thought it more probable that what was sublimed was a silico-sulphide of iron. He believed that oxy-sulphides of metals were formed more often than is generally supposed.

Mr. F. E. Pollard controverted the author's assumption that the sulphur exists in combination with the iron. He considered that sulphur exists almost entirely in combination with the manganese. The chairman said that silicon sulphide was not the indefinite substance the author imagined; three compounds—SiS_2 (white), SiS (yellow), and SiOS—had been isolated.

Then followed two papers by Mr. Charles A. Keller and Mr. Gustave Gin on the electrometallurgy of steel. They cover, in substance, the same field as their papers read before the American Electrochemical Society at the Niagara meeting, and abstracted in our June issue.

Production of Copper and Lead in the United States in 1908.

From two advance statements of the production of copper and lead in the United States in 1908, compiled by B. S. Butler and C. E. Siebenthal, respectively, and issued by the U. S. Geological Survey, we gather the following data:

The production of copper in the United States in 1908 was 942,570,721 lbs. This is the largest production ever made, exceeding that of 1906 by 24,765,039 lbs. and that of 1907 by 73,574,230 lbs., or 8.4 per cent. Among the States Arizona is first with 289,523,267 lbs., Montana second with 252,503,651 lbs., Michigan third with 222,289,584 lbs., and Utah fourth with 71,370,370 lbs.

The production of refined new copper of domestic origin in 1908 was 875,849,129 lbs., an increase of 91,577,702 lbs., or 11.6 per cent. over 1907. The total output of refined copper (exclusive of domestic scrap, etc.) by domestic refineries in 1908 was 1,094,700,123 lbs.

The production of refined copper in pounds in 1907 and 1908 is tabulated in the following table:

	1907		1908	
	Domestic origin.	Foreign origin.	Domestic origin.	Foreign origin.
Electrolytic	592,326,608	245,062,814	656,179,349	218,716,268
Lake	178,534,141	.....	195,503,099	.....
Casting	13,410,678	3,182,006	24,166,681	134,726
Total	784,271,427	248,244,820	875,849,129	218,850,994
Total output, domestic refineries	1,032,516,247		1,094,700,123	

The 1908 figures for domestic electrolytic include 26,786,485 lbs. lake copper which were refined electrolytically; those for 1907 contains 34,917,988 lbs. lake copper.

In addition to this production of refined copper, 9,705,103 lbs. (of which 2,551,077 lbs. were electrolytic and 7,154,026 lbs. were casting) were recovered during the year by the regular copper-refining companies of the country from domestic scrap, drosses, etc., and returns from practically all the known refiners of sec-

ondary material indicate that 13,508,574 pounds were turned out by them as casting copper and in alloys.

The production from secondary sources in 1908 was about 23,000,000 lbs., as compared with about 60,000,000 lbs. for 1907.

The production of lead in tons of 2,000 lbs. was 310,762 tons from domestic ore in 1908 (against 365,166 tons in 1907), and 97,761 from foreign ore and foreign base bullion (against 76,849 in 1907). The grand total from all sources is, therefore, 408,523 tons of lead in 1908 (against 442,015 tons in 1907). The total production of refined primary lead was 396,433 tons in 1908, the production of antimonial lead was 13,629 tons.

American Exposition in Berlin, 1910.

The American Exposition which will be held in Berlin in May, June and July, 1910, under the patronage of Prince Henry, is intended to bring together in a magnificent Exposition Palace (much larger than Madison Square Garden, New York) a representative collection of the best that American ingenuity, skill, and experience can produce, to foster and strengthen the trade relations of this country with Germany, and to increase American exports generally.

Mr. J. Pierpont Morgan and Mr. Thomas A. Edison have joined the honorary American committee. The Hamburg-American Line and the North German Lloyd have increased their original freight reduction by from 20 per cent to 30 per cent. Arrangements have been made whereby exhibitors who do not intend to send a special representative to Berlin, can have their exhibits unpacked, installed and demonstrated for a moderate charge by a special Sales Office and Bureau of Information established in the Exposition Palace.

Mr. Max Vieweger, Hudson Terminal Building, 50 Church Street, New York, is the American manager of the Exposition.

Melting Furnace Test.

Some interesting tests of a new Reyelbec furnace, built by the Hawley Down Draft Furnace Company, of Chicago, were recently made in Detroit. Two heats were made, one of 503 lb. and the other of 504 lb., in one hour and 15 minutes each, this time including the charging of the metal.

The metal consisted of a remelt of gates and valves and yellow ingot, the entire charge running 18 per cent or 20 per cent zinc. The metal was poured into an iron ladle and the temperature of the first ladleful was 1900 deg. The temperature of the second ladleful (after the ladle had become more thoroughly warmed) was 1990 deg. The metal in the furnace had, no doubt, a temperature of over 2150 deg.

The fuel consumption was a little over 18 lb. per 100 lb. of metal, but this could have been reduced by careful handling. In the tests no attempt was made to do anything extraordinary, but simply follow regular foundry practice. The Hawley Down Draft Furnace Company states that a melt can be completed within one hour, with a coke consumption not over 15 lb. or 16 lb. of coke per 100 lb. of metal.

New York Meeting of the American Electrochemical Society.

The autumn meeting of the American Electrochemical Society will be held, as usual, in New York City.

The intention is to hold the meeting on Friday and Saturday, Oct. 29 and 30. A meeting of the board of directors is to be held on Thursday evening, Oct. 28.

It is the intention to hold sessions for the reading of papers on Friday, Oct. 29, in the morning, at the Chemists' Club, and on Saturday morning another session at Columbia University, and possibly a third professional session in the afternoon. For Friday afternoon, excursions will be arranged. There will be an informal dinner on Friday evening, and arrangements will be made for entertainment of the visitors on Saturday night.

From all indications it appears that there will be a fine program of papers, while the local New York members will certainly do anything within their power to make all the visitors feel at home, so as to make the meeting a pleasant and enjoyable affair in every respect.

Measurement of High Temperatures by Thermo-Electric Pyrometers.

A paper presented by Dr. J. K. CLEMENT, of the United States Geological Survey, at the Rochester meeting of the American Ceramic Society, gives a good resumé of some fundamental principles of the measurement of high temperatures by means of the thermo-electric pyrometer.

The author first discusses the gas-thermometer, which is the standard, but not suitable for commercial use, and then takes up the use of the thermo-couple for temperature measurements. In 1830 A. Becquerel suggested the thermo-couple for the measurement of high temperatures, using a couple of platinum and palladium. In 1871 Tait introduced the platinum-iridium, and in 1886 Le Chatelier the platinum-rhodium couple. The platinum-rhodium couple is the most reliable one for high temperatures. Its range is from 300 deg. C. to 1600 deg. C. For lower temperatures, 0 deg. C. to 500 deg. C., the copper-constantan couple is available.

In the last few years a number of couples of base metal alloys have been placed on the market. Their range is limited, the upper limit varying from 1000 deg. to 1400 deg.

For the measurement of temperature two methods are in use: first, the galvanometer, and, second, the potentiometer method.

The former is by far the simpler method. It can be used by any intelligent operator and requires no special knowledge of the laws of electricity. Its sensibility is considerably less than that of the potentiometer method.

With a high-resistance galvanometer, 400 ohms, and proper precautions, the observations are reliable to about 5 deg. C. up to 1100 deg. C., and above this temperature to 10 deg. or 15 deg.

Many of the millivoltmeters now on the market, however, for use with thermo-couples, all pivoted instruments, are of low resistance, less than 5 ohms.

With such instruments the reading is dependent very largely on the resistance of the couples and leads, and since this varies with temperature and length of leads, the low-resistance instrument cannot be recommended for precision measurement.

For accurate laboratory measurements the potentiometer method is recommended. Its sensibility is 1 millivolt = 0.1 deg. C.

A third method of measuring the e.m.f. of a thermo-couple, which is capable of higher accuracy than the galvanometer method and is less cumbersome than the potentiometer method, is the current compensation method. Lindeck has designed an apparatus involving this principle.

It is advisable to calibrate thermo-couples from time to time in either of the following ways:

For comparison with a standard couple the greatest precaution should be observed to insure that both hot junctions are at the same temperature, e.g., by having the couples imbedded in a large mass of metal. A second method of calibration is by the determination of the points of fusion and ebulition of pure chemical substances, in particular metals. The points recommended by Dr. Clement are: cadmium, 322; zinc, 419; silver, 961; copper, 1084.

The values given are those of Holborn and Day, and are the ones accepted at present by the Reichsanstalt. Recently Dr. Day and Dr. Clement have found somewhat lower values.

Above 1100 deg. C., nickel (1435), iron (1505), and platinum (1720) may eventually be available. Until the gas-thermometer scale above 1100 deg. has been established, it is hardly advisable to use any point above the copper-point.

It is of the greatest importance that the metals used for fixed

points be of the highest purity, since the melting points are altered by the presence of impurity.

For the calibration of thermo-couples by means of fixed points two methods are in use: the wire method and the crucible method.

The former requires only a small amount of metal—less than a gram. The metal can be fused between the hot end of the two wires and the e.m.f. of the couple noted at intervals as the hot junction is gradually heated. The reading immediately before the circuit is broken gives the e.m.f. of the melting point. Also, the metal, in the form of fine wire, can be wrapped about the junction of the couple and the couple introduced into a furnace heated above the melting point. At the moment of fusion the galvanometer deflection halts momentarily.

There are several objections to this method. The metal fusing in contact with platinum wires is certain to alloy with the latter, thereby making them more readily fusible, besides altering the e.m.f. of the couple. Also, if the fusing metal is heated in the air, it is liable to oxidation and a consequent lowering of the melting point.

The crucible method is free from most of these sources of error. Holborn and Day used crucibles of porcelain and graphite of about 300 or 400 grams capacity. In most cases, iron excepted, graphite is preferable. In cases where the metal used is susceptible to oxidation, e.g., silver and copper, it is necessary to further protect against oxidation by a layer of powdered charcoal or graphite or by heating in a reducing (CO) atmosphere.

Frankenheim Method.—The couple, enclosed in a porcelain or quartz glass tube, is immersed in the metal, the furnace allowed to cool slowly, and the e.m.f. observed at regular intervals (30 seconds or 60 seconds). During the process of solidification the e.m.f. will remain constant. Similarly during fusion.

Sources of Error.—The error most frequently overlooked and easiest to correct is that due to the variation in the temperature of the cold junction. For laboratory measurements, the cold junction should be maintained at zero degree. In commercial work it should be maintained at a constant temperature, if practicable, e.g., 100 deg. C. Otherwise the temperature of the cold junction should be noted and the correction applied: $t = t_{obs} + 0.5 \times$ temperature cold junction.

An error, almost inevitable under practicable working conditions, is that arising from the contamination of the wires and their consequent inhomogeneity. Metallic vapors, iridium especially, readily attacks platinum, producing a change in its thermo-electric properties. The drop in the e.m.f. due to contamination may amount to 50 deg. C., or even 100 deg. C. It is, therefore, highly desirable that when couples are used in furnaces in which slagging materials or reducing gases, or both, are present, the wires should be enclosed in a protecting tube, wrought iron, for example.

A couple once contaminated cannot be restored to former conditions except by removing the injured portion. The readings of a couple, when it is new and free from impurity, e.g., homogeneous, are independent of the depth of immersion. In a contaminated couple it is necessary to avoid temperature variations along the wires, since the inhomogeneity produces a condition in which the couple behaves like a series of almost infinitesimal couples. In the calibration of a contaminated couple, the depth of immersion should be the same as in working conditions.

A fourth source of error, brittleness in the wires, can be remedied by annealing.

Dr. Clement finally calls attention to two further sources of error in temperature measurements, which, however, are not in the thermo-electric circuit. In furnaces operating under reduced pressure the entrance of cold air through an opening around the pyrometer tube will produce a lowering of temperature. Also in the measurement of the temperature of gases, a low temperature may be produced by the conduction of heat along a tube or wires, and by radiation to cooler walls.

CORRESPONDENCE

Dictionary of Chemical and Metallurgical Material.

To the Editor of Electrochemical and Metallurgical Industry:

Sir:—I have just received your Dictionary of Chemical and Metallurgical Material.

Knowing where to get things is second only in importance to knowing where to get information, and your Dictionary furnishes the latter about the former, and consequently has a quadratic importance.

Hollywood, Cal. Henry Noel Potter.

[Out of several hundred letters which we have received with respect to our Dictionary, we publish the note of Dr. Potter because it emphasizes pointedly our intentions in publishing this Dictionary. It is intended as an annual; and to improve it in future editions, we request detailed criticisms from all who use the Dictionary. One copy of the Dictionary has been sent free of charge to every one on our mailing list. Any of our readers who can add to its usefulness by detailed criticisms, is asked to kindly send them at an early date.—Editor.]

Atomic Weights.

To the Editor of Electrochemical and Metallurgical Industry:

Sir: Referring to Dr. Hinrichs' outline of his method for the calculation of atomic weights, published in your July issue, allow me to point out, for the benefit of our case-hardened and unimaginative analysts, wherein I think the theories adduced are well worthy of sympathetic consideration.

Dr. Hinrichs' method amounts really to a systematizing of error, of the difference E, and no student of physical science can deny that in doing this he is working along a perfectly scientific line of research, be it theoretical or practical. The search for the correct n^{th} decimal in an atomic weight by mechanical methods is worthy and useful—furthermore, it is "respectable," but it does not include mathematical consecration of the results and compels an agnostic attitude. It is this mathematical consecration or adjustment of results, which men with Dr. Hinrichs' mental attitude are seeking to give us. All honor and gratitude be to them.

It is true that Dr. Hinrichs believes in even numbers and natural fractions for all atomic weights, and as far as I can see, this still remains an open question. If differences exist they must do so according to some system, even if we have trouble in discovering its elements. If departures from whole numbers and natural fractions do really exist, they may, as I have recently pointed out (*Nature*, Feb. 18, 1909, p. 459), be connected with the disintegration of the atom as advocated by the most advanced school of physical chemists, and I suggested a test of the validity of this theory. It would seem that atomic disintegration would necessarily imply differences of electronic content for each element varying with the elapsed time from the previous critical limit at which the break-down from a higher element to a lower one took place.

If this loss of electrons is taking place, the elements in one world of space, having all a common origin in point of time, would have substantially identical atomic weights for different lots tested, but those from other worlds would differ from them. The iron or nickel in a meteorite, especially if its origin were extraneous to the solar system, might yield atomic weights quite out of keeping with those of iron and nickel found on this planet.

If a test of this character can be carried out, it seems to me that the theory of the continual degradation of matter will be either proven or else rendered very doubtful. If the theory is sound, the electronic losses of an element must be in definite relation to the age of that element, and therefore work of systematizing, such as that of Dr. Hinrichs, is, as I have already stated, of the highest scientific order.

Paris, France. Alfred Sang.

Conductivity, Porosity, and Gas Permeability of Refractory Materials.

BY S. WOLOGDINE AND A. L. QUENEAU.

Introduction.

BY A. L. QUENEAU, Consulting Metallurgical Engineer, Philadelphia, Pa.

A great difficulty in designing furnaces and estimating the probable loss of heat by conduction through the furnace walls is due to the practically total lack of reliable information as to the heat conductivity of refractory materials.

It is true that a number of determinations have been made since Peclet undertook the first experimental work, but, unfortunately, the experiments have always been carried on under conditions that do not occur in industrial furnaces.

The importance of the knowledge of the heat conductivity coefficients cannot be overestimated in modern metallurgy, especially in neometallurgy, the field of the electric furnace, where the cost of the heat units is of such economical importance. Heat conductivities of furnace materials should be as available and as readily used as are the electrical conductivities. I might add, however, that a great deal of research work remains to be done in that latter field, especially in the electric conductivity of molten metals, slags and salts.

In view of the lack of knowledge that has prevailed in metallurgical engineering as to the properties of the materials in daily use, it is very gratifying to be able to welcome the remarkable paper read by M. S. Wologdine before the recent Congress of Applied Chemistry in London. He gives us, for the first time, a systematic study of the heat conductivity, porosity and gas permeability of the commercial refractory materials; the author is to be congratulated upon giving the full details of all tests and description of the apparatus used as well as of the difficulties that had to be surmounted.

It is to be regretted, however, that the range of the temperatures at which the determinations were made did not extend beyond 1000°, with the exception of a few instances in which temperatures of nearly 1200° were recorded.

When it is considered that the heat conductivities increase quite rapidly with the temperature, the importance of determining the coefficients of heat conductivity within the industrial range from 1000° to, say, 1700° C. is clearly seen. Silica, magnesia and chrome bricks would very seldom be used if the temperature of the furnaces was not to be higher than 1000°. However, in the absence of data covering the industrial temperature range, use of the figures obtained at 1000° C. may now be made without undue error resulting.

The following has suggested itself to the writer by the study of the paper of Wologdine:

(1) Proper regard being given to the fusibility of the brick, all clay bricks, terra-cotta, building bricks, firebricks, have practically equal coefficients of heat conductivity. The coefficients are differentiated in this class of refractory materials solely by the temperature of burning and not by the character of the clays or by their chemical composition.

(2) In all refractory materials, including the special bricks, such as chrome, magnesia, carborundum, graphite, the heat conductivity is a direct function of the temperature of burning. I am inclined to include as subject to this rule the amorphous carbon and the graphite electrodes, though this has not yet been confirmed by actual determination to my knowledge.

(3) The great value for heat insulation purposes of silica brick when burned at a moderate temperature, 1050° C., is due to the fact that their coefficient of heat conductivity is practically equal to that of Kieselguhr brick and only one-half that of clay brick. It is desirable that further determinations be made in this regard by independent observers.

(4) The unique characteristic of chrome bricks is that their coefficient of heat conductivity is independent of the temperature.

(5) There are remarkable and often enormous variations in the permeability to gases of the same bricks with the increase in temperature. In one instance the permeability changed from 3.3 liters per hour to 241 liters per hour. This shows the importance of scientifically selecting the clay mixtures for a given work as for crucibles or retorts where, as in zinc metallurgy, the permeability to gases has a material influence on the metal recovery. In this connection the nil permeability of graphite crucibles is to be noted. Perhaps the same results might be obtained at a much reduced cost by substituting clay flakes for the graphite flakes as proposed by H. Putz (German patent 198, 840, Sept. 29, 1907).

(6) To secure efficient heat insulation, refractory materials should be burned at the lowest allowable temperature. This burning temperature is generally known; it is the maximum temperature to which the bricks will be exposed in the furnaces. The use of the maximum temperature is necessary in order to prevent the brick from shrinking any further when set in the furnace walls. Though this last fact is well known, it is often neglected, and a shortening of the furnace life is the result.

(7) The gas permeability of the bricks of blast furnace linings must have an important bearing on their life, owing to the destructive action of carbon monoxide in contact with the iron oxide present in the brick. (B. Osann, *Stahl und Eisen*, 1627, 1907.)

The following table has been prepared from the figures given by M. Wologdine:

No.	Material	Conductivity		
		Gr. cal. sec. per sq. cm. per cm. per 1° C. diff.	Kg. cal. Hour per sq. m., per m. per 1° C. diff.	Relative Conductivity
1	Graphite brick	.025	9.0	100%
2	Carborundum brick	.0231	8.32	92.4
3	Magnesia brick	.0071	2.54	28.4
4	Chromite brick	.0057	2.05	22.8
5	Fire brick	.0042	1.50	16.7
6	Checker brick	.0039	1.42	15.8
7	Gas retort brick	.0038	1.36	15.2
8	Building brick	.0035	1.26	14.0
9	Bauxite brick	.0033	1.19	13.2
10	Glass pot	.0027	.96	12.4
11	Terra cotta	.0023	.84	9.3
12	Silica brick	.0020	.71	7.8
13	Kieselguhr brick	.0018	.64	7.1

The figures selected are representatives of the grade of refractory materials that are available for every-day furnace work; the figures for extra pure or inferior grades have been omitted as tending to obscure the issue.

This table in the absence of data for the higher industrial range from 1000° to 1700° C. offers the most reliable data at hand.

* * *

Conductivity, Porosity and Gas Permeability of Refractory Materials.*

BY S. WOLOGDINE.

(Translated by A. L. Queneau.)

The important place which refractory materials occupy in modern industry demands an accurate knowledge of their physical and chemical properties; this knowledge is required not only in their manufacture, but also for their economical applications.

Consideration of the insulating properties of the refractory materials, i. e., the heat conductivity and gas permeability, is of the utmost importance in the construction of furnaces and in the manufacture and use of bricks, retorts, crucibles, etc. These properties have a direct bearing on the fuel utilization.

Until lately the fusibility and the alterability under the influence of the various disintegrating forces, physical, chemical and mechanical, have only been considered insofar as these characteristics have a more direct influence on the successful operation of industrial furnaces.

It had long been noted that the harmful influence of high

*A paper read at the London Congress of Applied Chemistry.

temperature and the corrosion of furnace walls by the charge materials were affected by the difference in temperature between the interior and the exterior of the furnace. This temperature difference, the heat gradient, is a direct function of the heat conductivity of the materials forming the walls; the steeper the heat gradient the thinner is the portion of the wall subjected to the influence of the furnace temperature—a temperature which may be near the softening point of the wall components.

La Société d'Encouragement pour L'Industrie Nationale granted me a research scholarship to make a study of the heat conductivity, porosity and gas permeability of the ordinary refractory materials and clay products. The work was carried on in the laboratories of Professor LeChatelier at the Sorbonne and the Ecole des Mines and under his general supervision.

The materials tested may be classified as follows:

1st, Mixtures for refractory materials.

2d, Mixtures for stoneware and porcelains.

3d, Mixtures for earthenware and terra cotta.

4th, Mixtures for building bricks.

Round flat plates or bricks were made (Fig. 1) from these various mixtures in most cases in duplicate sets which were burned at different temperatures in order to observe the influence of the burning temperature on the physical properties. The plates were presented by metallurgical and ceramic works and were made from current commercial mixtures.

TABLE I.

Number	Type of Brick	Marks	Proximate Chemical Analysis	Temperature of Burning	Depth of the Thermo-Couples Holes		
					a_1	a_2	a_3
			Refractory Bricks.				
				Deg. C.	*Cms.*	*Cms.*	*Cms.*
1	Fire brick			1200	.5	4.	4.6
2	" "	RA–5	SiO_2=78, Al_2O_3=18, Fe_2O_3=3.3, CaO=.5%	1050	.7	4.5	4.9
3	" "	RA–9		1300	.7	4.4	4.85
4	" "	RB–5	SiO_2=66, Al_2O_3=29, Fe_2O_3=4, CaO=.5%	1050	.5	4.45	4.9
5	" "	RB–9		1300	.65	4.7	4.95
6	Checker brick	2		....	.7	4.5	5.0
7	" "	4		....	.5	4.5	5.5
8	Gas retort mixture	20		....	.55	4.5	5.0
9	" " "	20		....	.92	4.5	5.0
10	Bauxite	Bx–5	SiO_2=28, Al_2O_3=66, Fe_2O_3=5	1050	.6	4.5	4.8
11	"	Bx–9		1300	.5	4.5	4.9
12	Silica	S–5	SiO_2=94, Al_2O_3=2, CaO=2	1050	.5	4.6	5.0
13	"	S–9		1300	.6	4.5	5.1
14	Magnesia	M–5	SiO_2=1, Al_2O_3+Fe_2O_3=.5, MgO=95	1050	.7	3.8	5.0
15	"	M–9		1300	.5	4.75	5.0
16	Magnesia from Euboea	M	Fe_2O_3 higher than in No. 14 and No. 15	....	.7	4.2	5.
17	Euboea & Vallauris Mag	MV–47		....	.6	3.75	5.
18	" " " "	MV–50		....	.6	4.1	4.95
19	" " " "	MV–56		....	.9	4.4	5.1
20	Glass Monkey Pot	P_1	Same mixture	Green	.6	3.8	5.25
21	" " "	P_2		1200	.75	4.3	5.3
22	" " "	P_3		1600	.65	4.25	5.2
23	" " "	B–4		Green	.8	4.5	5.35
24	" " "	B–5		1200	1.0	4.4	5.25
25	Carborundum	CA–5	SiC=87, SiO_2=12, Fe_2O_3=.4	1050	.5	4.5	5.
26	"	CA–9		1300	.7	1.95	5.15
27	"	C–5	SiC=75, SiO_2=20, Al_2O_3=3, Fe_2O_3=1, CaO, MgO=1	1050	.5	4.6	5.1
28	"	C–9		1300	.6	4.7	5.2
29	Graphite	P–18	C=48.5, SiO_2=30.5, Al_2O_3=18, Fe_2O_3=2	710	.5	4.3	4.5
30	"	P–5		1050	.6	3.9	4.35
31	"	P–9	" " " "	1300	.6	3.9	4.35
32	Chromite	Ch–1–23	Same mixture	....	.5	4.5	5.1
33	"	Ch–1–36	" "	....	.6	4.5	5.1
34	"	Ch–1–39	" "	....	.5	4.5	5.05
35	"	Ch–2–59	" "	....	.5	4.4	5.0
36	"	Ch–2–26	" "	....	.5	4.5	5.1
37	"	Ch–2–45	" "	....	.5	4.3	5.0
38	"	Ch–2–60	" "	....	.5	4.4	5.0
39	"	FA–5	" "	1050	.65	4.55	4.9
40	"	FA–9	" "	1300	.65	4.25	4.8
41	"	F–9		1300	.5	4.85	5.25
42	Kieselguhr	K		....	.5	3.9	4.4
43	Graphite	QR/204–54		....	.5	4.5	4.85
44	"	QR–68 / 204		....	.65	4.2	4.85
			Stonewares and Porcelains.				
45	Stone-ware	GT–5	Same mixture	1050	1.0	4.3	5.05
46	"	GT–9	" "	1300	.9	4.1	4.8
47	"	G–44–5	" "	1050	1.25	4.15	5.2
48	"	G–44–9	" "	1300	1.1	4.05	5.0
49	"	G–152–5	" "	1050	1.0	4.15	4.95
50	"	G–152–9	" "	1300	.9	4.15	5.0
51	"	G–189–5		....	.8	4.0	4.8
52	Porcelain (Sévres)	PN	SiO_2=69.4, Fe_2O_3+Al_2O_3=23.61, CaO=1.22, K_2O=2.58, Na_2O=2.42	1300	.45	4.15	4.6
53	" "	PD	SiO_2=60.75, Fe_2O_3+Al_2O_3=32, CaO=4.15, K_2O+Na_2O=3.02	1400	.45	3.95	4.45
54	Stone-ware (Sévres)	PD–67	SiO_2=79.32, Al_2O_3+Fe_2O_3=18.42, K_2O+Na_2O=2.14	1300	.05	4.45	4.85
			Building Bricks and Terra Cotta.				
55	White building brick	TCB–5		1050	.9	4.2	4.85
56	" " "	TCP		1050	.6	4.3	4.9
			Mixtures For Red Building Bricks.				
57	Red brick	T–2/5 T–2–40 / 5	SiO_2=75, Al_2O_3=14, Fe_2O_3=6, CaO=3, MgO=2	1050	.6	3.8	4.8
58	" "		" " " " "	1050	.5	2.15	4.65
59	" "	T–3–42 / 5	SiO_2=74, Al_2O_3=16, Fe_2O_3=6.5, CaO=2.5, MgO=1	1050	.6	4.3	4.9
60	" "	T–3–7 / 5	" " " " "	1050	.8	4.8	5.1
61	Vallauris clay	V–48		....	.5	4.7	5.1
62	" "	V–51		....	.6	4.9	5.1
63	" "	V–57		....	.7	4.55	5.0
64	Light clay	L–52		....	.6	4.0	5.0
65	"	L–58		....	.75	4.5	5.0

The plates, which were 50 mm thick, had four identical series of holes, all 2.5 mm in diameter. In each series the first hole was pierced through the plate, the second hole was 5 mm. deep and the third 45 mm deep.

The plates were first used in the determination of the heat conductivity and then cylinders 45 mm in diameter of the full thickness of the plates were cut out of them, the cylinders serving for the density, porosity, and permeability determinations.

In Table I is given the list of the materials investigated, together with the proximate chemical analysis, the burning temperature, and the depth of the holes for the thermo-couples. It will be noticed that the depth of the third hole is equal to the thickness of the plate.

Heat Conductivity.

The apparatus used for the determination of the heat conductivity is shown in Fig. 2. The test plate *g* placed in the cover *e* was heated by means of the gas furnace *f*. The heat flow through the plate was measured by the water calorimeter *C*.

Temperature determinations were made simultaneously at the following points: First, at the lower surface of the plate *g*;

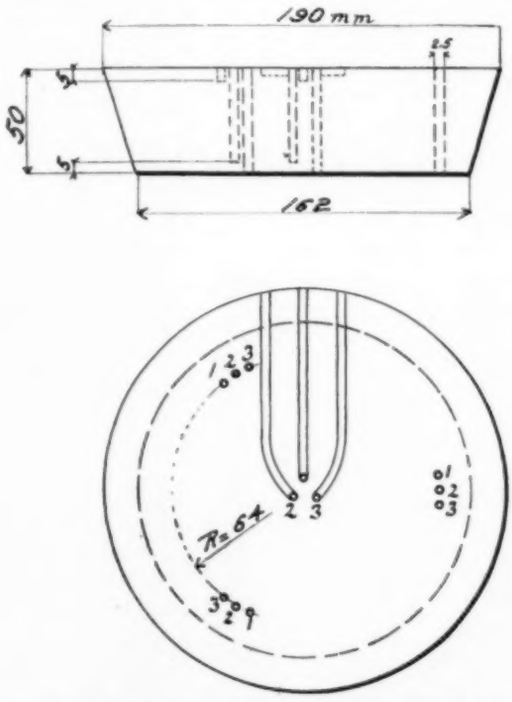


FIG. 1.—TEMPERATURE MEASUREMENTS IN SAMPLES.

second, 5 mm above the lower surface; third, 5 mm below the upper surface; thus it was possible to establish the relation between the heat flow and the heat gradient in the interior of the plate, and to calculate the coefficient of heat conductivity; i.e., the quantity of heat expressed in gram-calories passing in one second through a section of 1 sq. cm with a variation of temperature of one degree per centimeter of depth. The uniform heating of the plate was secured by placing the small pieces of brick *d* near the chimney *T*. Temperature measurements made with LeChatelier thermo-couples placed in the four series of three holes, Fig. 1, showed that the heat distribution was sufficiently uniform to warrant the use of a single series of holes, the series centrally located. The thermo-couples were made of platinum and 10 per cent platino-rhodium wires 0.1 mm in diameter. The wires of the thermo-couples were insulated in the holes by fine silica sand moistened with water glass and above the holes by asbestos thread. By means of a suitable switching device *R*, the one galvanometer *G* served for the three thermo-couples.

Before testing, the plates were treated as follows:

The two faces were made approximately parallel by rubbing; this is absolutely necessary to secure perfect contact between the calorimeter and the plate.

Three grooves leading to the holes of the central series were cut in the plate to receive the insulated thermo-couple wires, which were thus below the calorimeter (Fig. 1).

The depth of the central holes and the thickness of the plates were carefully measured.

The water calorimeter *C* had a diaphragm with a central open-

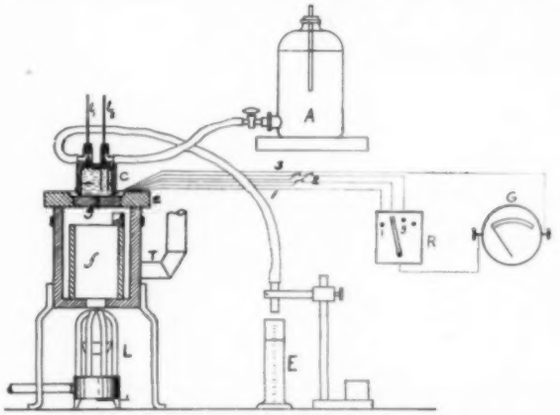


FIG. 2.—DETERMINATION OF HEAT CONDUCTIVITY.

ing to insure the thorough mixing of the different water currents; the uniform temperatures indicated by the thermometer t_1 and t_2, graduated in tenths, demonstrated the necessity of the diaphragm. The quantity of water passing from the Mariotte bottle *A* through the calorimeter during a given time was collected and weighed. When the temperature equilibrium had been established, simultaneous pyrometer readings were made on the thermo-couples 1, 2 and 3.

The modus operandi of a test was as follows:

The furnace being started, the temperature was allowed to rise gradually without placing the calorimeter on the plate under test. When the equilibrium of temperature between the heat given by the flame and lost by radiation to the air was established, the calorimeter was put in place and the water made to flow, new temperature determinations were made, and the test was completed when the equilibrium was reached under the new

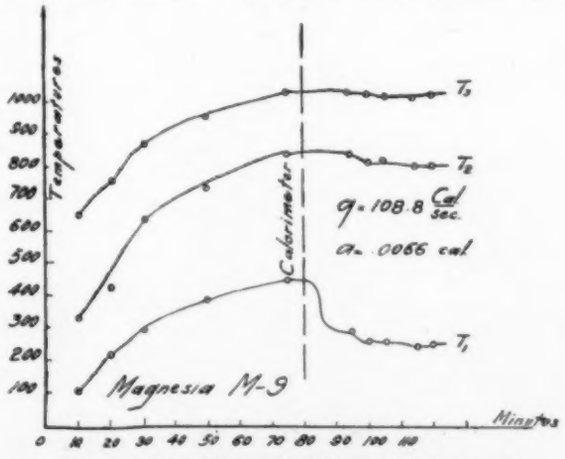


FIG. 3.—TEMPERATURE VARIATIONS DURING A TEST.

conditions; from time to time the regularity of the water flow was checked by collecting the water during a given time in a graduated glass.

The diagram Fig. 3 gives the temperature variations during a test made on a magnesia brick. The temperature equilibrium was obtained 80 minutes after starting; by the placing of the calorimeter a new equilibrium was established 30 minutes later. The curve T_1 gives the temperature changes in the section of

the plate 5 mm below the calorimeter; the sudden drop took place soon after placing the calorimeter in position. The curve T_2, corresponding to a point 45 mm below the calorimeter, presents but a small modification, while the curve T_3 shows the uniform temperature at the lower surface of the plate throughout the test.

In order to compute the coefficient of heat conductivity, the hypothesis was made that the line representing the heat variations through the thickness of the plate, i.e., the heat gradient,

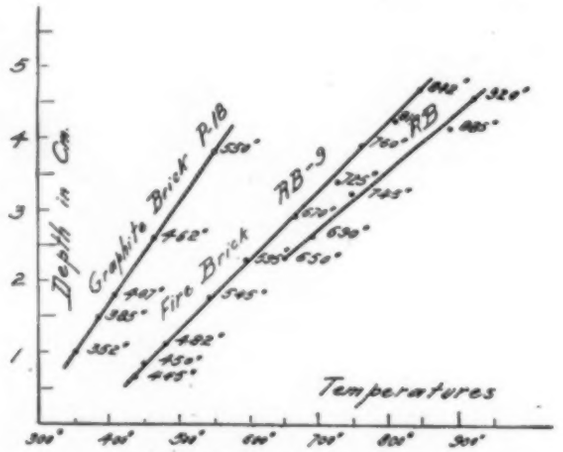


FIG 4.—HEAT GRADIENT CURVES.

is a straight line passing through the two points representing the temperatures T_0 and T_5 of the two parallel faces of the plate. This makes it possible to determine the two temperatures T_0 and T_5 by interpolation. The truth of the hypothesis was experimentally demonstrated by directly measuring at various points the temperatures in different plates which were heated until the equilibrium had been established.

The results are shown in Fig. 4.

The detail of the calculation for the determination of the coefficient of heat conductivity for the magnesia brick M-9 is given in Fig. 5.

Let T_1, T_2, T_3 represent the temperatures given by the thermocouples, t_1 and t_2 the temperatures of the water as it enters and leaves the calorimeter, P the quantity of water that passed through it in grams per minute. By interpolation the temperatures T_0 and T_5 of the upper and lower faces of the brick are obtained. The quantity of heat Q traversing per second an area equal to that of the calorimeter bottom is

$$Q = \frac{P\,(t_2 - t_1)}{60}$$

The coefficient of heat conductivity is

$$a = \frac{S\,(T_5 - T_0)}{QL}$$

S being the area of the bottom of the calorimeter in square centimeters and L the thickness of the plate in centimeters.

In the test given in Fig. 5 (magnesia brick M-9) $T_1 = 265°$, $T_3 = 807°$, $T_3 = 1020°$ (temperature of the furnace), $t_1 = 14.9$, $t_2 = 21.3$, $l = 5$, $S = 125.68$ cm², $P = 1020$ gr.,
then

$$Q = 108.8 \text{ gram calories,}$$

and $a = .00066$ gram caloric unit of conductivity.

The differences of temperature between the upper face of the brick and the average temperature of the calorimeter water on one hand, and between the temperature of the lower face and heat of the flame on the other hand, supply useful data regarding the heat equilibrium.

In the test M-9 the differences were as follows:

$$T_0 - 18° = 182°$$
$$T_5 - T_3 = 180°$$

When the two temperatures obtained in this way showed too great a difference the test was repeated.

The heat conductivities obtained have been computed:

First, in gram calories for 1 deg C. difference of temperature, 1 sq. cm surface, 1 cm thickness in one second.

Second, in kilogram calories for 1 deg. C. difference of temperature, for 1 sq. m, 1 m thickness in one hour. (Table III.)

For most of the refractory materials the heat conductivities vary between 500 deg. and 1000 deg.; within those limits the changes are not very large, and for practical purposes it is sufficiently accurate to take the arithmetical mean of the coefficients corresponding to the temperatures between these two limits; these are the figures given in the fourth and fifth columns of Table III.

Firebrick.

Marks	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories
Bricks Burned at 1050°:			
RA-5	145	1010	.0038
"	125	840	.0036
Average			.0037
RB-5	250	1220	.0037
"	205	1095	.0032
Average			.0035
Bricks Burned at 1300°:			
RA-9	310	1000	.0054
"	205	725	.0048
Average			.0051
RB-9	225	1085	.0039(?)
"	230	925	.0044
"	225	620	.0042
Average			.0042

From Table (*a*) it is seen that the conductivity of firebricks increases with the temperature, and that the conductivity increases with the temperature of burning.

Checker Brick.

Marks	Temperature of Upper Surface T_0	Temperature of Lower Surface T_5	Conductivity Gram-Calories
2	185	1.005	.0035
2	85	706	.0030
2	110	563	.0036
Average			.0034
4	112	825	.0043
4	115	730	.0036
Average			.0039

Table (*b*) refers to checker bricks from the Paris Gas Company regenerative illuminating gas furnaces*, while Table (*c*) refers to bricks made from the same mixture as used by the Paris Gas Company for their illuminating gas muffles.

Brick from Gas Retort Mixture.

Marks	Temperature of Upper Surface T_0	Temperature of Lower Surface T_5	Conductivity Gram-Calories
20/3	140	1120	.0040
"	175	1110	.0040
"	160	1050	.0039
"	150	1010	.0040
"	140	990	.0038
"	151	870	.0037
"	105	685	.0035
Average			.0038
20/5	195	1125	.0041
"	110	930	.0038
"	150	92[illegible]	.0037
"	150	865	.0036
Average			.0038

The last two tables show clearly the increase of the heat conductivity with the temperature. This is further illustrated in Fig. 6 in the gas-retort bricks.

Bauxite Brick.

Marks	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
Bx-5	150	1140	.0030	Burned at 1050
"	160	1120	.0033	
Average			.0031	
Bx-9	170	1155	.0035	Burned at 1300
"	170	965	.0031	
Average			.0033	

By burning at 1300 deg. the heat conductivity of the bricks is increased 1.5 times that of those burned at 1050 deg. The heat conductivity increases slightly with the temperature.

Silica Brick.

MARKS	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
S-9	147	1015	.0033	Burned at 1300°
"	165	1015	.0033	
"	140	1000	.0031	
"	145	1000	.0031	
"	160	805	.0029	
"	165	735	.0031	
Average			.0031	
S-5	110	1005	.002	Burned at 1050°

*Damour-Queneau—Industrial Furnaces, pages 88 and 89.

The measurements with the bricks M-5, M-9 represented great difficulties, owing to their small cohesion, being almost pure magnesia (95 per cent MgO), especially in case of the brick M-5, burned at 1050 deg.

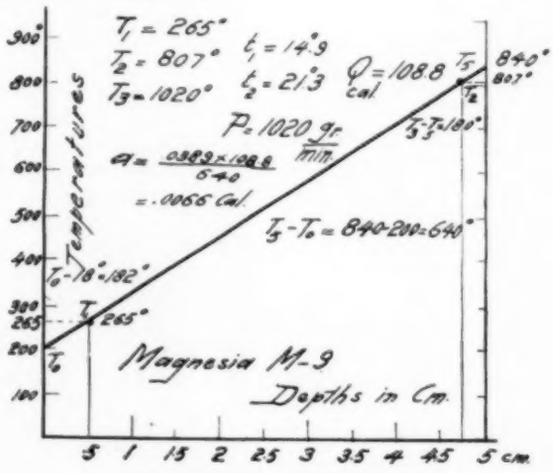


FIG. 5.—TEST OF MAGNESIA BRICK.

The coefficients for the brick M-9, burned at 1300 deg., vary regularly from 0.006 to 0.0072.

The brick M-53, regular commercial magnesia brick, is higher in iron, lime and silica than the purer brick, and has also higher heat conductivity coefficients.

Magnesia Brick.

MARKS	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
M-5	230	1000	.0058	Burned at 1050°.
M-9	185	915	.0060	" " 1300°.
"	200	840	.0066	Both bricks were of high-grade Magnesia, white and very pure.
"	155	795	.0062	
"	180	745	.0064	
"	200	720	.0064	
"	165	700	.0072	
"	134	530	.0070	
Average			.0065	
M-53	260	970	.0072	This brick is much higher in iron than the brick M-5-9.
"	215	885	.0075	
"	130	675	.0065	
Average			.0071	
MV/47	115	910	.0035	The bricks MV/47, 50, 56 are of very much lower grade than the first bricks, being lower in MgO and higher in F_2O_3.
"	105	695	.0036	
Average			.00355	
MV/50	90	905	.0035	
"	50	485	.0036	
Average			.00355	
MV/56	130	1130	.0030	
"	115	980	.0031	
"	70	705	.0027	
Average			.0029	

The bricks MV-47, 50, 56 are not true magnesia bricks in the generally accepted meaning of the term, being high in clayey material; their conductivity is practically that of firebricks.

The bricks were made from the mixtures used in the manufacture of glass pots.

Besides the green bricks and those burned at 1200 deg., a third specimen burned during 60 days at 1600 deg. was also tested. The increase of conductivity with the temperature of burning

Bricks Made from Glass Pots Mixture.

MARKS	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
P-1	57	565	.0025	Green brick.
P-2	190	1035	.0026	Burned at 1200°.
"	90	640	.0023	
Average			.00245	
P-3	255	990	.0048	Burned for a long time at 1600°.
"	140	615	.0042	
Average			.0045	
B-4	80	560	.0031	Green brick.
B-5	175	1150	.0029	Burned at 1200°.
"	100	670	.0025	
Average			.0027	

is very marked, the conductivity of the brick burned at 1600 deg. being practically double of that of the brick burned at 1050 deg.

The experimental determinations for bricks of such high conductivity presented difficulties due to the heating of the calorimeter by radiation; the extreme hardness of the brick made difficult any attempts to remedy defects in them. This

Carborundum Brick.

MARKS	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
CA-5	280	750	.015	Burned at 1050°.
"	270	690	.014	
"	265	680	.014	
"	255	660	.015	
Average			.0145	
CA-9	300	650	.019	Depth of ag was too small (1.95 mm.)
"	230	440	.027	
Average			.023	
C-5	205	1210	.0032	Burned at 1050°.
"	200	1165	.0032	
"	155	1075	.0036	
"	160	1065	.0034	
"	155	870	.0033	
Average			.0033	
C-9	420	1000	.015	Burned at 1300°.
"	355	775	.017	
"	290	730	.014	
"	280	720	.013	
"	225	555	.013	
Average			.014	

explains the irregularity of the results obtained. The influence of the carborundum contents is very marked. The conductivity increases also with the temperature of burning.

Owing to the possibility of burning the graphite in the face

Graphite Brick.

MARKS	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
P-18	180	900	.0061	Test conducted with oxidyzing flame; resulting in the burning of some of the graphite.
"	175	855	.0055	
"	162	685	.0063	
"	130	620	.0053	
"	115	420	.0061	
Average			.0059	
P-5	200	660	.013	Loss in graphite.
"	215	595	.015	
"	210	565	.015	
Average			.014	
P-9	405	865	.019	As above.
"	175	405	.018	
Average			.0185	
QR-54/204	330	600	.024	Test conducted in reducing atmosphere. No loss of graphite.
"	295	550	.024	
Average			.024	
QR-68/204	430	705	.026	
"	285	485	.024	
Average			.025	

of the brick in contact with an oxdizing flame, widely different results may be recorded. The great heat conductivity may also affect the calorimeter by radiation.

The figures for the bricks QR/54 and QR/68 only are representative of this class of bricks, as bricks P-5, 9, 18 had the

graphite burned out for a depth of several millimeters,[1] the bricks appearing white on the lower face after the test.

The influence of the temperature of burning is also to be noted.

Chromite Brick.

Mark	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
FA-5	160	1120	.0026	Bricks made of Chrome Ore with a clay binder.
"	215	1075	.0031	
"	115	955	.0026	
Average			.0028	
FA-9	125	1180	.0034	FA-5 burned at 1050
"	115	805	.0034	FA-9 " " 1300
Average			.0034	
F	70	1125	.0025	Pure Chrome Ore, very porous brick.
"	105	675	.0025	
Average			.0025	
Ch-1-23	235	895	.0068	CH-1-23 and CH-1-36 are denser than the following bricks: Ch-1-39, Ch-2-59-26-45.
"	150	510	.0070	
Average			.0069	
Ch-1-36	170	620	.0072	
"	125	575	.0062	
"	125	565	.0063	
"	150	500	.0066	
Average			.0066	
Ch-1-39	170	600	.0062	
Ch-2-59	295	1190	.0060	
"	210	855	.0058	
"	205	820	.0052	
"	220	805	.0058	
"	145	570	.0057	
Average			.0057	
Ch-2-26	155	900	.0056	
"	110	655	.0054	
Average			.0055	
Ch-2-45	240	985	.0044	
"	280	950	.0050	
"	175	540	.0046	
Average			.0047	
Ch-2-60	260	1025	.0053	
"	185	960	.0056	
Average			.00545	

The bricks Ch-1 and Ch-2 may be considered true chromite bricks; the bricks FA-5-9 being too high in clay contents, the heat coefficient of the latter is practically that of firebrick. The heat coefficients for Ch-1 and Ch-2 appear to remain independent of the temperature. Brick F, of pure chromite, was very porous.

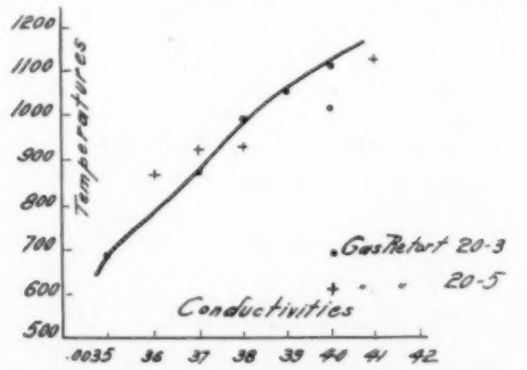


FIG. 6.—INCREASE OF HEAT CONDUCTIVITY WITH TEMPERATURE.

Kieselguhr Brick.

Mark	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories
K	140	910	.0020
"	100	630	.0016
Average			.0018

These bricks have a remarkably low coefficient of conductivity and a low apparent density.

Their manufacture is difficult, owing to the change of volume that takes place during burning, when the hydrated silica loses its water. A single specimen among six received was available.

[1] The influence of a porous zone free from graphite, and of a few mm. in thickness, is very noticeable on the heat conductivity; this passing from .025 to .018, a difference of 30 per cent. Translator.

All the mixtures tested, mixtures for products of widely different applications in the arts, when burned until vitrified,

Bricks Made of Stoneware Mixtures.

Marks	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories	Remarks
GT-5	115	845	.0033	Not vitrified.
"	70	610	.0031	" "
Average			.0032	" "
GT-9	200	1000	.0052	Vitrified.
"	135	675	.0047	"
Average			.00495	"
G-44-5	110	930	.0029	Not vitrified.
"	75	670	.0032	" "
Average			.00305	" "
G-44-9	160 (?)	1000	.0053	Vitrified.
"	160	675	.0042	"
Average			.00475	"
G-152-5	115	990	.0034	Not vitrified.
"	105	800	.0033	" "
Average			.00335	" "
G-152-9	70	655	.0040	Vitrified.
G-189-5	105	860	.0038	Not vitrified.
67	280	795	.0045	Vitrified.

have a higher conductivity than any of the clay and silica mixtures. The conductivity of the plates made from the same mixture but burned at a temperature lower than the vitrification point is practically that of clay bricks. All these bricks show the influence of the temperature of heating on the conductivity.

White Terra Cotta.

Marks	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories
TCB-5	60	860	.0033
TCP	203	875	.0038
"	195	830	.0036
Average			.0037

These mixtures used in the manufacture of architectural white bricks, terra cottas, etc., were burned at a low temperature; the coefficient of conductivity is equal to that of fire bricks burned at low temperature.

Red Bricks and Terra Cotta.

Marks	Temperature of Upper Surface	Temperature of Lower Surface	Conductivity Gram-Calories
T-2-5	255	1000	.0034
"	260	840	.0033
"	175	720	.0038
Average			.0035
T-3-7	135	695	.0035
T-3-42	65	965	.0029
"	115	765	.0028
"	95	660	.0027
Average			.0028
V-48	80	860	.0033
"	55	530	.0024
Average			.00285
V-51	100	865	.0024
"	90	710	.0024
Average			.0024
V-57	125	1100	.0025
"	105	1080	.0026
"	60	795	.0023
"	15	655	.0018
Average			.0023
L-52	110	1135	.0026
"	95	885	.0024
"	60	550	.0022
Average			.0024
L-58	95	1120	.0023
"	95	995	.0024
Average			.00235

Under this heading were included mixtures for building bricks, roof tiles, etc.; the temperature of burning is low and the heat coefficient is the same as that of the preceding bricks.

From an examination of Table III (October issue) it is seen that all mixtures with a clay basis, when burned at 1050 deg. C., have an equal coefficient of conductivity equal to about 0.003.

When burned at a higher temperature than that of 1300 deg. the coefficient is notably higher, 0.0045.

Silica brick have a lower conductivity than the clay bricks if burned below the temperature at which quartz is transformed into trydimite. The conductivity of magnesia brick is about double that of clay bricks. Graphite and carborundum bricks have a conductivity nearly five times that of clay bricks. Finally, Kieselguhr brick has the lowest heat conductivity coefficient, 0.0018; i.e., equal to only half that of clay brick.

For all bricks the heat conductivity increases with the temperature of burning. This conductivity increases with the temperature.

(To be concluded.)

Furnace Electrode Losses.

By C. A. Hansen.

Comparative Oxidation Rates of Carbon and Graphite: Historical.—Some work along this line has been done by previous investigators, but so far as the writer knows, no figures have been published other than those of Moissan (Le Four Electrique), who determined the lowest temperatures at which some varieties of carbon would oxidize. In general, his conclusions were that amorphous carbons oxidize at temperatures as low as 375° to 490° C., while graphite did not oxidize below 665° to 690° C. This work was all done on powders, apparently, not on carbons made up into shapes with binders and subsequently baked. Collins (ELECTROCHEM. AND MET. IND., II, 277), FitzGerald (*Ibid.*, III, 9) and Johnson (*Ibid.* II, 335) all say that graphite offered "greater resistivity to combustion than amorphous carbon."

Procedure.—The following work was suggested in 1905 by Prof. C. F. Burgess at the University of Wisconsin and was carried out in his laboratory by Mr. C. P. Hatter and the writer at that time.

Carbon and graphite rods were clamped into larger graphite blocks, to which current connections were made, the apparatus being arranged as shown in Fig. 1. A variable resistance was connected in series. When a rod was to be heated this resistance was all cut out, and as the rod heated the resistance

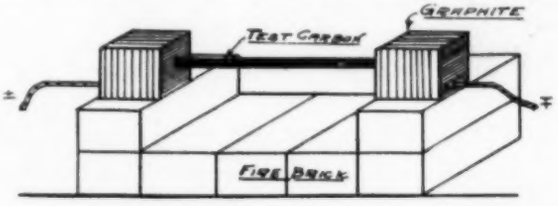


FIG. 1.—APPARATUS FOR TESTING RATE OF OXIDATION.

was put back into the circuit. In this way the test rod could* be brought to the desired temperature in from 5 to 8 seconds. Since each rod was kept at an approximately uniform temperature, as indicated by a Wanner pyrometer, for 15 minutes, the heating interval cannot have been a serious variable any more than the cooling interval, which was perhaps 10 seconds before the temperature of the rod fell below 600° C.

The rods were dried, weighed and micrometered before test and after test they were brushed lightly, weighed and micrometered again. Loss per square centimeter of surface exposed per minute was calculated on the basis of the average of the two sets of dimensions.

In Fig. II the results have been plotted. The carbons gave points which are fairly close to a straight line. The graphite points were averaged arithmetically and the straight line drawn through the calculated points. It is significant that only one graphite point falls below the carbon line.

The results do not, however, show that graphite is more readily oxidized than amorphous carbon, for a rather curious reason. When a graphite rod is heated to 1300° or 1400° it throws off particles of graphite, many of which are so large that they are not completely burned when they leave the rod,

OXIDATION OF CARBON (NATIONAL CARBON CO.).

Sizes of Samples. cm.	Length Exposed. cm.	Temp.	Loss. Grs. cm.²/min.	Loss. cm. depth/hr.
[1] 1.0 x .63	29	925°C.	.0062	.232
" "	"	990	.0073	.273
" "	"	1019	.0093	.348
" "	"	1137	.0107	.402
" "	"	1209	.0115	.433
" "	"	1250	.0120	.450
" "	"	1305	.0121	.453
" "	"	1305	.0126	.472
" "	"	1305	.0132	.488
" "	"	1353	.0159	.596
" "	"	1369	.0148	.555
" "	"	1412	.0142	.532
" "	"	1412	.0146	.548
" "	"	1412	.0143	.536
" "	"	1425	.0145	.545
" "	"	1425	.0146	.548
" "	"	1491	.0165	.618
" "	"	1522	.0166	.622
" "	"	1522	.0193	.724
" "	"	1522	.0171	.642
" "	"	1713	.0192	.720
" "	"	1762	.0193	.724
" "	"	1789	.0231	.865
" "	"	1907	.0196	.735
" "	"	1930	.0199	.746
1.3 diam.	23	1303	.0133	.500
" "	"	1412	.0146	.548
.63 "	20	1412	.0145	.545
" "	"	1305	.0128	.480

[1] A fresh sample used for each measurement.

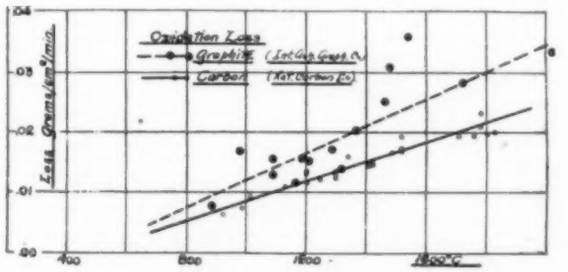


FIG. 2.—CURVES OF OXIDATION LOSS.

OXIDATION OF GRAPHITE (INTERNATIONAL ACHESON GRAPHITE CO.).

Sizes of Samples, cm.	Length Exposed, cm.	Temp.	Loss. Grs. cm.²/min.	Loss. cm. depth/hr.
[2] .6 diam.	10	895°C.	.0078	.283
" "	"	980	.0169	.615
" "	"	1090	.0151	.513
" "	"	1090	.0129	.470
" "	"	1194	.0155	.565
" "	"	1208	.0150	.545
" "	"	1281	.0170	.618
" "	"	1375	.0202	.735
" "	"	1485	.0311	1.130
" "	"	1544	.0358	1.305
" "	"	2030	.0335	1.220
1.2 "	23	1166	.0119	.433
" "	"	1305	.0139	.506
" "	"	1468	.0251	.923
" "	"	1738	.0274	1.000

[2] A fresh sample used for each measurement.
All samples were micrometered to .001. Dimensions given are approximate.

but can be collected on a sheet of asbestos, held underneath the heated rod. All of those graphite samples which gave very high loss values behaved in this way. Some of them did not throw off particles when heated, notably the one subjected to the highest temperature (2030° C.). None of this was noted with the carbon samples heated.

The explanation perhaps lies in the greater porosity of the graphite, which enables the binder carbon to be oxidized, the originally bound particles falling away when this takes place.[1]

* It was found that the carbon samples heated quite uniformly from contact to contact while the graphite samples might be 1300° C. in the middle and only 600° C. at the graphite block terminals. When small carbon bushings were interposed between the graphite sample ends at the terminal blocks, the temperature was found to be quite uniform throughout the entire length of sample. On the whole, this experiment is the most striking illustration of comparative heat conductivities I have run across in this work.

[1] The porosity of graphite electrodes (as calculated from a bulletin issued by the Acheson Graphite Co.) = 1 — 1.6/2.25 = 28.8 per cent. The porosity of amorphous carbon electrodes (same bulletin) = 1 — 1.6/2 = 20 per cent.

Merely to show that the falling off of the graphite particles was due to oxidation, however, a rod which showed a decided tendency to flake off was heated in CO to a temperature in excess of 2000° C. The loss was .002 grs./cm²/min. This loss was probably due to traces of CO_2 or O_2 in the CO.

That graphite in itself is really less readily oxidized than amorphous carbon is indicated by this observation:

When a carbon article composed of graphite and amorphous carbon, bound together in the ordinary way, is burned because of careless handling in the process of manufacture, the surface of that article will always, in the writer's own experience, at least, be highly graphitic.[2] In fact, one of the workmen here brought in a motor brush which he had "graphitized" accidentally at a temperature not in excess of 400° C., as a refutation of the commonly accepted idea that extremely high temperatures were necessary for graphitization.

Progressive Oxidation.—The original surface of a baked carbon article is made up of a skin of relatively dense carbon, very thin, which in all probability is due to the breaking down at the surface of the volatile hydrocarbons driven out from the binder pitch in the baking process. The question of porosity raised above would indicate a less rapid oxidation rate for this surface. An attempt was therefore made to distinguish between the rate of oxidation of the fresh surface and of the surface left when the skin was burned away.

Progressive Oxidation of Carbon.—Successive four-minute heats on same sample.

Size of Sample, cm.	Length Exposed, cm.	Temp.	Grs. Loss per cm. ²/min.
1.0x.63	29	1261	.0113
	"	"	.0123
	"	"	.0129
	"	"	.0131
	"	"	.0128
	"	"	.0134
1.0x.63	"	1243	.0112
	"	"	.0118
	"	"	.0129
	"	"	.0120
	"	"	.0135
	"	"	.0143
	"	"	.0148
Graphite—same treatment.			
1.3 dia.	20	1243	.0139
	"	"	.0151
	"	"	.0158
	"	"	.0159
	"	"	.0159

The results obtained indicate a somewhat lower oxidation rate at the start.

Discussion.—As regards the application of the results above given it is, of course, realized that they cannot be made use of in predetermining the electrode consumption for a furnace. The consumption of electrodes depends so largely upon the degree of exposure to oxidizing influences; whether the electrodes are embedded in reducible material, as is the case with all ferro alloy furnaces; whether, in case of Girod or Héroult furnaces, the charging doors are tightly closed, etc.

It is, however, reasonably certain that in ordinary furnace use graphite electrodes are not inherently superior to carbon electrodes on the score of resisting oxidation.

As an instance of the importance of cutting down the oxidation loss of electrodes, the following case may be cited:

Some time ago a small Héroult furnace of 300 lb. charge capacity was built (described in Electrochem. and Met. Ind., May, 1909): This furnace was fitted with 4-in. x 4-in. x 40-in. graphite electrodes, and it was found possible to melt a 300-lb. charge in it with 150 kw-hours. Shortly afterward a slightly larger furnace of 600 lb. charge capacity was built and likewise fitted with 4-in. x 4-in. x 40-in. electrodes. It was repeatedly found that the power required was greater per unit charge than with the smaller furnace in the ratio of about 1.2 to 1.0. When the larger furnace was fitted with 6-in. x 6-in. x 40-in. graphite electrodes it showed a slight advantage in power consumption over the 300-lb. furnace so long as the electrodes retained the square 6-in. x 6-in. end.

As soon as the electrodes became pointed the power consumption increased. The difference between full square end and sharp point on electrodes made a power consumption difference of fully 30 per cent.

The difference must be due partly to the fact that the square-end electrode distributes the heat more uniformly, and partly to the screening by the electrode end of the roof from the direct radiation of the arc. It has been noticed repeatedly in laboratory work with small steel furnaces that sore eyes and roof troubles go with pointed electrodes, an evidence of the screening action of the full-sized electrode end.

Now all electrodes used in the Héroult furnace, at least, tend to oxidize to a point as shown in Fig. III (No. 4), and one of the electric steel furnace pioneers of this country argued that while he realized the power saving, due to the use of large tip electrodes, he might as well buy the smaller and cheaper electrode, since they all became pointed in a short time, anyway.

We have tried to coat electrodes with the intention of cutting down electrode oxidation. Electrodes No. 3 and No. 4, Fig. III, are 4-in. x 4-in. x 40-in. graphites worked together for several runs in a 300-lb. Héroult furnace without water cooling. No. 3 was coated with a paste of carborundum and water glass (density about 1.15). Where the water glass-carborundum coating sticks its enormous advantage is easily recognized. We have not yet, however, found a convenient way of making it stick uniformly.

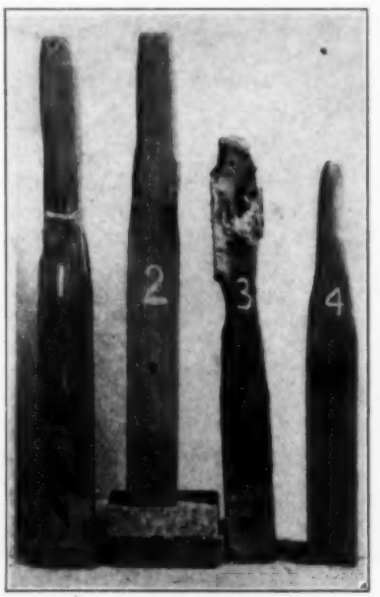


FIG. 3.—OXIDATION OF ELECTRODE ENDS.

Electrodes No. 1 and No. 2 of the same figure are respectively of carbon and graphite and were worked together without water cooling at 125 amp per square inch in a 600-lb. Héroult furnace. The high current density made the carbon electrode the hotter of the two and it oxidized more than the corresponding graphite. The graphite electrode is raised to make up just the original difference in length.

The disadvantage of the carbon electrodes is also well shown in the same cut. Note the break marked with white paint. The break was not due to excessive current densities.

Fig. IV shows the same disadvantage with an 18-in. x 18-in. x 72-in. carbon in which the current density never exceeded 27 amp per square inch.

In the latter case the breaking of the electrode necessitated the tearing down of the furnace. The time lost in replacing the electrode permitted the furnace charge to cool to such an extent that it was impossible to get enough power back into it to start it off again.

These last incidents are mentioned merely to emphasize the point that there are troubles other than oxidation troubles and to emphasize the need of carefully made carbon electrodes. There is nothing inherent in the nature of carbon that makes perfect electrodes impossible. The results argue for carbon electrodes when properly made for use in steel furnaces, etc., for, since a large electrode-end area is advantageous on the score of power economy, large section electrodes and consequent low-current density must be used. When low-current

[2] This applies up to 1400° C. at least. The following sentence, of course, might indicate that the mixed carbons had been exposed at temperatures below those at which graphite would oxidize at all, according to Moissan, which was not the case, as a rule.

densities are used the main inherent advantage of graphite over carbon—its low electrical resistivity—dwindles in impor-

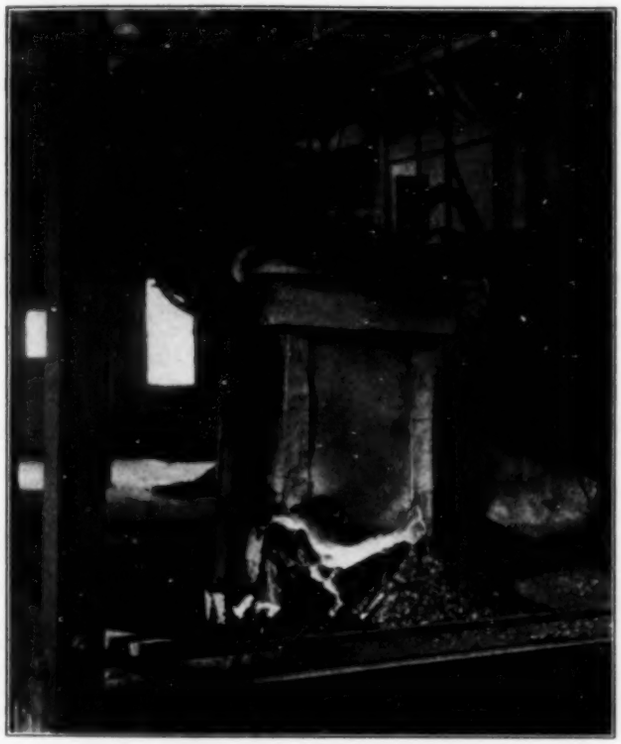


FIG. 4.—ELECTRIC FURNACE.

tance and the main inherent disadvantage of graphite over carbon—its high heat conductivity—becomes of extreme importance.

RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

Melting Iron in a Foundry Cupola.

BY PROF. H. MCCORMACK.

This article follows along the same line as the one previously published on the same subject in the January issue, 1908, of this journal (Vol. VI, page 20). We have endeavored to make our data more complete than was possible in the former article, and have corrected some of the errors which appeared in the first attempt to accurately account for all the heat developed in the foundry cupola. The accompanying data was taken on a heat as ordinarily conducted by the foreman in our foundry:

REPORT ON HEAT IN FOUNDRY OF ARMOUR INSTITUTE OF TECHNOLOGY, NOVEMBER 12, 1909.

The charge was:

Coke	240	kg
Scrap iron	727	"
Pig iron	363.5	"
Limestone	70	"

The charge was arranged as follows:

Bed charge of coke	136	kg
Scrap iron	363	"
Coke	22.7	"
Scrap iron	91	"
Pig iron	91	"
Limestone	18	"
Scrap iron	91	"
Coke	27.1	"
Pig iron	91	"
Limestone	18	"
Coke	27.1	"
Scrap iron	91	"
Pig iron	91	"
Limestone	18	"
Coke	27.1	"
Scrap iron	91	"
Pig iron	91	"
Limestone	16	"

There was obtained from the heat:

Slag	119.5	kg
Coke	53	"
Clean castings	1070	"

The blast was turned on at 3:37 and the bottom dropped at 4:44, giving a run of 67 minutes. The temperature of the escaping gases was taken every three minutes with a Whipple temperature indicator; the average temperature was 155° C. at the time the blast was turned on and the highest temperature was 1280° when the bottom was dropped. The average temperature was 800° C.

The temperature of the metal was taken at each tapping with a Thwing radiation pyrometer. The lowest temperature was 1700° C. The average temperature was 1900° C.

The blast velocity, pressure and volume were taken. The average blast pressure was static head 4.5 in. of water, the dynamic head 5.076 in. of water. The mean radius of the discharge orifice was 3 in.

The velocity head, in feet of air, was 37.1. The velocity of the air in the pipe was 48.9 ft. per second. From this we calculate that 19.1 cu. m of air were moved per minute.

ANALYSIS OF MATERIALS.

Constituents.	Scrap.	Pig Iron.
Silicon	2.12	2.50
Graphitic carbon	2.65	4.19
Combined carbon	0.55	0.25
Total carbon	3.20	4.44
Manganese	0.45	0.550
Sulphur	0.066	0.030

	Calculated Constituents of the Charged Metal.	Composition of the Cast Iron as Analyzed.	Loss or Gain.
Silicon	2.24	2.30	+ 0.06
Graphitic carbon	3.16	2.35	— 0.81
Combined carbon	.45	0.60	+ 0.15
Total carbon	3.61	2.95	— 0.66
Manganese	0.61	0.55	— 0.06
Phosphorus	0.303	0.390	+ 0.087
Sulphur	0.054	0.035	— 0.019

The coke:

Total carbon	89.5
Sulphur	0.196
Phosphorus	0.005
Ash	10.43
Calories, per kilogram	7129

The ash of the coke consisted of:

Silicon dioxide	49.04
Ferric oxide	29.46
Alumina	8.46
Calcium oxide	4.65
Magnesium oxide	3.21
Sulphur	0.94
Phosphorus	0.50

The analysis of the limestone was:

Silicon dioxide	0.24
Ferric oxide	0.88
Aluminum trioxide	0.27
Calcium oxide	30.60
Magnesium oxide	21.25
Sulphur	0.00
Phosphorus	0.00
Carbon dioxide	47.18

The analysis of the slag was:

Silicon dioxide	51.67
Ferric oxide	12.59
Metallic iron	7.50
Aluminium trioxide	1.35
Maganese oxide	8.92
Calcium oxide	12.76
Magnesium oxide	5.23
Sulphur trioxide	0.44
Phosphorus pentoxide	0.00

Calculation of calories developed:

The coke's calorific value was determined in the Mahler bomb calorimeter and found to be 7129 calories per kilogram. Coke used, $240 - 53 = 187$ kg. Hence, $7129 \times 187 = 1{,}333{,}100$ calories.

Silicon dioxide reduced to silicon $0.0006 \times 1090 \times 7407 = 4844$ calories absorbed. Carbon to carbon dioxide, $0.0066 \times 1090 \times 8080 = 58{,}127$ calories.

Total calories:

Coke	1,333,100
Silicon of iron supplied with	4,844
Carbon of iron	58,127
	1,386,383

The escaping gases:

Total volume, 1280 cubic meters.

Carbon dioxide	14.0 %	Volume 179	cu. M. Wt. 139 kg
Carbon monoxide	9.0 %	Volume 110.2	cu. M. Wt.
Oxygen	0.0 %		
Nitrogen	77.0 %		

Calculation of calories utilized:

(*a*) TO MELT THE IRON AND SUPERHEAT TO 1900° C.

Weight of iron, 1090 kg.
Specific heat, 0.1124 solid; 0.22 liquid.
Melting point, 1200° C.
Heat of fusion, 69 calories per kilogram.
To raise to melting point:

$$0.1124 \times 1090 \times 1200 = 147{,}030 \text{ calories.}$$

To fuse the iron:

$$69 \times 1090 = 75{,}210 \text{ calories.}$$

To superheat to 1900° C.:

$$022 \times 700 \times 1090 = 167{,}860 \text{ calories.}$$

Total calories in iron, 390,100.

(*b*) CALORIES OF SENSIBLE HEAT IN ESCAPING GASES.

Average temperature of air, escaping from cupola 800° C.
Mean specific heat at 800° = 3246.
Volume of air per minute = 19.1 cu. m.
Duration of heating, 67 minutes.

$$800 \times 0.3246 \times 19.0 \times 67 = 332{,}350 \text{ calories.}$$

(*c*) CALORIES OF LATENT HEAT IN ESCAPING GASES.

9.0 per cent of carbon monoxide.
Total volume of gases, measured at 15° C., and 760 mm pressure, 1280 cu. m.

$$1280 \times 9.0 \div 100 = 115.2 \text{ cu. m of carbon monoxide.}$$

Carbon monoxide weighs 1.2499 kg per cubic meter.

$$115.2 \times 1.2499 = 143.98 \text{ kg.}$$

Carbon monoxide burning to carbon dioxide gives 2410 calories per kilogram; hence, $143.98 \times 2410 = 347{,}010$ calories.
Total heat in gases, $332{,}350 + 347{,}010 = 679{,}360$ calories.

(*d*) CALORIES UTILIZED IN SLAG FORMATION.

70.0 kg of limestone decomposed.
119.5 kg of slag formed.
To decompose limestone:

$$167.68 \times 70 = 11{,}737.6 \text{ calories.}$$

To form slag:

$$550 \times 119.5 = 65{,}725 \text{ calories.}$$

Total heat for slag:

$$65{,}725 + 11{,}737.6 = 77{,}462.6 \text{ calories.}$$

(*e*) HEAT UTILIZED IN HEATING UP CUPOLA.

Inner diameter, 0.56 m.
Height of pyrometer, 2.0 m.
Thickness of brick, 0.11 m.
0.835 sq. m are of brick lining of the cupola.
Average temperature, 700° C.

$$2 \times 0.235 = 0.47 \text{ cu. m of brick heated.}$$

Specific heat, 0.26; specific gravity, 2.2; hence, $0.47 \times 1.00 \times 2.2 \times 9.26 \times 700 = 188{,}190$ calories.

(*f*) HEAT UTILIZED IN HEATING UNBURNED COKE.

Amount of coke, 93.0 kg.
To heat to 250° C. we have, $93 \times 0.201 \times 250 = 4673$ calories.
To heat from 250° C. up to 1900° C. we have, $93 \times 0.2337 \times 1650 = 35{,}861$ calories.
Total, 40,534 calories.

Summary of calories utilized:

	Per cent of total.
(*a*) To melt and super-heat iron 390,100	28.14 per cent.
(*b* and *c*) To heat gases and as CO 679,360	49.00 "
(*d*) To form and heat slag 77,462.6	5.60 "
(*e*) To heat cupola 189,588	13.60 "
(*f*) To heat unburned coke 40,534	2.90 "
(*g*) Lost by radiation and convection 8,00 (Estimated from results by Andrews.)	0.58 "
Total calories accounted for, 1,385,044.6	99.82 "
Calculated calories, 1,386,383	100.00 "
Unaccounted for, 1,339	0.18 "

We expect the calories unaccounted for to usually be greater than this, as the methods employed are not accurate to this degree. In this experiment there must be counter-balancing errors which give us this small percentage of heat unaccounted for.

The experiment noted above was performed primarily to secure data on the utilization of the heat developed during melting. The results secured in this experiment are somewhat different from those previously reported.

In the experiment previously reported all of the items were not accounted for as closely as they are in this one and the loss by radiation was taken by difference instead of by direct determination. In this set of data we note that the heat applied to the iron is about 28 per cent of the total heat developed. This high percentage is undoubtedly due to the short duration of the melting.

In the original data from which the foregoing calculations are made we find that the temperatures of the escaping gases during the first part of the melting are very much lower than during the latter portion of the melting. The percentage of carbon monoxide is also greater toward the conclusion than at the beginning. We usually find that during the first part of the melting, when charging is going on and when the cupola is full of metal, nearly to the charging door, the temperature of the escaping gases will not rise much above 750° C., while as soon as the charging ceases and the metal commences to descend in the cupola, the temperature will rise to about 1000° C. and the percentage of carbon monoxide will be about three times what it was at the beginning of the heat. Another considerable percentage of the heat in the present experiment was utilized in heating the foundry cupola. This percentage would, of course, be very much diminished in a heat of longer duration.

The items mentioned, the heat in the gas and that needed to heat the cupola, amount to over 50 per cent of the total.

The percentage of the heat in this experiment, found to be applied directly to the iron, is about the same as that commonly ascribed. Thus, Richards, in his metallurgical calculations, assumes that 32 per cent of the total heat is applied to the iron, but does not state how this figure is derived. The efficiency of the cupola in our experiment, calculated in the usual way, would be 28 per cent.

It seems to me, however, that calculating in this way is somewhat inaccurate, as in melting in any furnace, the furnace itself has to be heated, slag is to be formed and heated and these items, at least, should be credited to the efficiency of the furnace.

Aside from the thermochemical data here presented, there are seemingly some other items of interest. For example, the change in composition of the metal on remelting.

Comparing the changes noted in this paper, with some previously published, we find that there are some differences. Probably the earliest account of the influence of remelting is found in Turner's Iron (The Metallurgy of), in which he reviews some work done in 1853 and quotes the analyses of this metal as obtained by himself in 1886.

The table of his analyses, together with his comments on the same, is given below.

No. of Melting.	Total Carbon.	Combined.	Silicon.	Sulphur.	Manganese.	Phosphorus.
1	2.67	0.25	4.22	0.03	1.75	0.47
8	2.97	0.08	3.21	0.05	0.58	0.53
12	2.94	0.85	2.52	0.11	0.33	0.55
14	2.98	1.31	2.18	0.13	0.23	0.56
15	2.87	1.75	1.95	0.16	0.17	0.58
16	2.88	...	1.88	0.20	0.12	0.61
18	...	2.20	...	...	...	...

"It will be noticed that, owing to the oxidizing effect of remelting, the proportion of silicon steadily diminished, while sulphur was at the same time absorbed from the furnace gases. The natural effect due to these changes was produced upon the condition of the carbon, which, instead of being almost wholly graphitic, became nearly all combined, thus producing a hard, white iron, which was deficient in tenacity, and brittle.

"The elimination of manganese with the silicon, the increase in the percentage of phosphorus due to its concentration in a smaller quantity of metal, and the initial increase of total carbon for a similar reason, are all in accordance with what is observed whenever iron is melted in the air, and when the resulting slag is not strongly basic."

The results just given were obtained by melting the metal in an air furnace. Turner then quotes some other data obtained by melting in a foundry cupola. I quote his comments and analyses.

"In ordinary practice a cupola is employed. Here the oxidation is greater, while as the iron melts in contact with the fuel it more readily absorbs sulphur. As a consequence, though the changes which take place are of the same kind, and follow the same order as that previously given, the effect of each melting is more marked." This is illustrated by the following analyses, from experiments conducted by Jungst in the Imperial Foundry at Gleiwitz:

	1st Melting.	2d Melting.	3d Melting.
Carbon, graphitic	2.73	2.54	2.08
Carbon, combined	.66	.80	1.28
Silicon	2.42	1.88	1.16
Sulphur	.04	.10	.20
Phosphorus	.31	.30	.28
Manganese	1.09	.44	.36

In "General Foundry Practice," McWilliam and Longmuir say: "In remelting an ordinary gray iron mixture there is, as a rule, a loss of about 0.2 to 0.3 per cent of silicon. Unless the total carbon be abnormal, this will not change much; but, if abnormally low, it will tend to increase to a normal amount by reason of contact with the coke, and hence very low carbon mixtures cannot be successfully melted in the cupola; a good reason why the melting of steel-casting mixtures in the cupola, as has been attempted by more than one firm, has not met with success. The manganese will decrease to a variable extent, 0.2 to 0.3, representing a typical loss if about 1 per cent is present in the charge, while with a low manganese content (like 0.3 per cent) the loss may be almost nil. The phosphorus comes out practically according to calculation; while the sulphur, again, owing to contact with the fuel, will be found to have increased, an increase seldom less than 0.02 per cent, unless with exceptionally pure coke or with a charge initially high in manganese, the manganese in the latter case apparently combining with the sulphur in the metal and taking it into the slag."

Hoffman, in his "Iron and Steel," quotes some results published by Beckert on the influence of remelting.

Hoffman's statements and the analyses by Beckert we quote as follows:

"Every melting of a metal is connected with loss. In melting down cast iron in a furnace, the components would be more or less oxidized by the action of CO_2 in the order of their affinity to O, viz: Mn first, then Si, C, and Fe, were it not that iron predominated strongly over the other elements, and protecting them entered to a considerable extent into the slag, where it is found in larger amounts than Mn and Si. Beckert illustrates by subjoined table the change cast iron may undergo by remelting four times.

Melt.	Before.	After first.	After second.	After third.	After fourth.
C	2.154	3.682	3.641	3.560	3.463
Si	2.096	1.846	1.688	1.619	1.549
Mn	0.768	0.537	0.441	0.336	0.105

From the references quoted, we note that there is a silicon loss, a gain of combined carbon and a loss of graphitic carbon, these taken together give a loss of total carbon on each remelting.

There is also noted a gain of sulphur. The statement is usually made that all of these two later elements present in the metal charge will be found after melting as constituents of the cast iron.

In this our own experiment, as well as in several others which we have conducted, the results of which as yet are not quite ready for publication, we find either no loss of silicon or a slight gain; that there is only a slight gain of phosphorus, and that the sulphur also shows no increase.

I ascribe these effects to the slag which we always endeavor to have present. Its composition is given along with the analyses of materials.

We are carrying on other experiments along these lines upon which we hope to report from time to time.

Armour Institute of Technology,
Chicago, Ill.

The Construction of Gas Producers.

BY DR. OSKAR NAGEL.

We distinguish two fundamental types of producers.

The first and oldest has been developed from the blast furnace and is a vertical shaft in which the fuel moves downward, while the air and the gas travel in the opposite way. The gas formed passes through the green fuel, carrying along water and volatile matters. The shaft is built of firebricks and surrounded by a wrought-iron shell. The tops of the producers are sometimes made of an arch of firebricks, but frequently only provided with

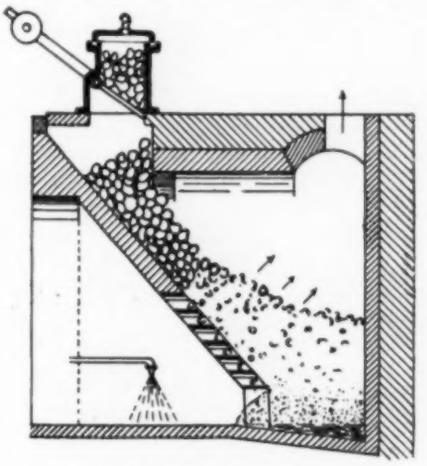


FIG. 1.—SIEMENS PRODUCER.

water-cooled covers made of iron. Cast steel is also sometimes used for the parts that are exposed to considerable heat. The shaft is generally circular, sometimes, however, square. The walls are mostly vertical, sometimes showing wider and narrower portions, as will be seen from the illustrations.

Fixed rules as to the interior shape cannot be given, different fuels requiring a different treatment. The main consideration must be to provide for the increase of volume of certain coals during the period of distillation; for this reason the shaft is enlarged down to the zone of reduction. The walls near this zone should be vertical so as to prevent, as far as possible, the slag from sticking. At the bottom end the shaft

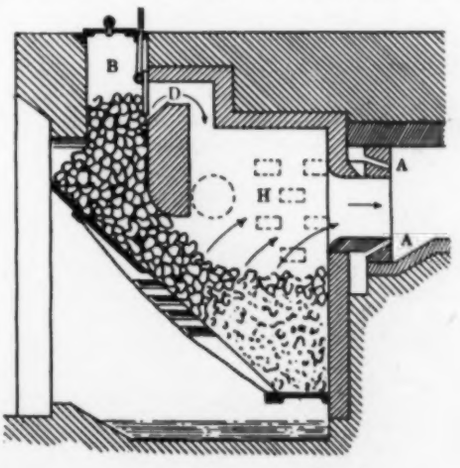


FIG. 2.—"HALF-GAS FIRING."

is frequently made narrower in order to force the air straight upward, instead of along the side walls. Such a narrowing will never do any harm, as at this point the volume of the fuel is already considerably decreased by the partial combustion. Vertical walls facilitate uniform downward travel of fuel.

Poke holes are generally provided in the cover and in the side walls, in order to make it possible for the fireman to reach the interior layers of fuel and to break up the clinker.

Since in a vertical shaft the fuel is easily kept at uniform height, the shaft producer is used to-day *almost* exclusively,

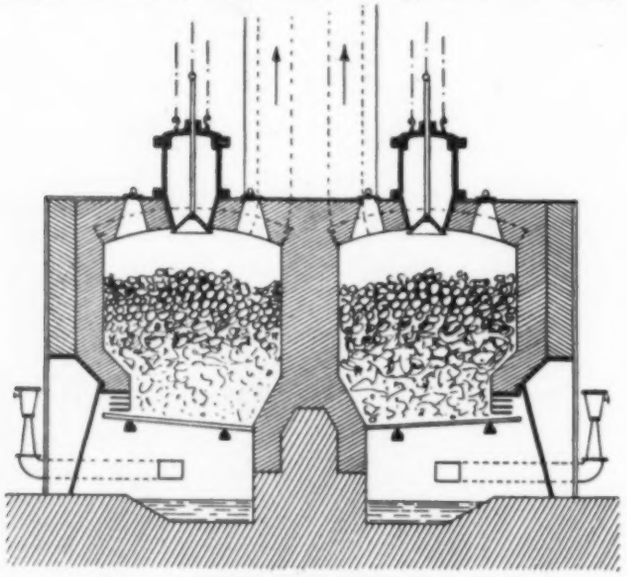


FIG. 3.—MODIFIED SIEMENS PRODUCER.

but *always* in cases where the producer plant is not directly connected to the furnace.

The second type, which was developed by Siemens, is used when producer and furnace are built in one unit (Fig. 1). The fuel is charged through a hopper provided at the top and passes over an inclined firebrick wall, which, at the bottom is continued as a stepgrade.

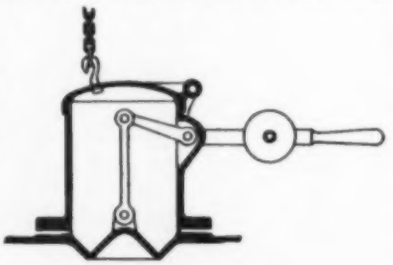


FIG. 4.—HOPPER.

The Siemens type of producer offers less resistance to the passage of the gas through the fuel bed than the shaft type, as in the latter the gas has to travel through the entire height of the coal contained in the producer. For this reason blowers are used in producers of the shaft type, while in Siemens producers in many cases natural draft, produced by a stack behind the furnace, is employed; this, however, frequently necessitates a reduction of the fuel layer and thereby causes incomplete gasification.

FIG. 5.—EBELMAN METHOD.

The loss produced by the last-mentioned fact is not very considerable, as the gas produced is directly and immediately used and pretty nearly all the heat passing from the producer to the furnace utilized. If, on the other hand, the gas would be cooled before being used, very considerable losses (up to 40 per cent or 50 per cent) would result. Therefore, shortly after the introduction of the Siemens producers addition of water was employed by arranging a water pan in the ash pit and producing the steam by the radiating heat.

Within the class of Siemens producers we must also include the so-called "half-gas firings," which are especially used for low-grade fuels. These firings are not supposed to produce complete gasification. The gas produced contains much carbon dioxide. For utilizing the monoxide, an additional supply of air is introduced in the combustion place.

In the charging hopper *B* (Fig. 2) tarry gases and steam are

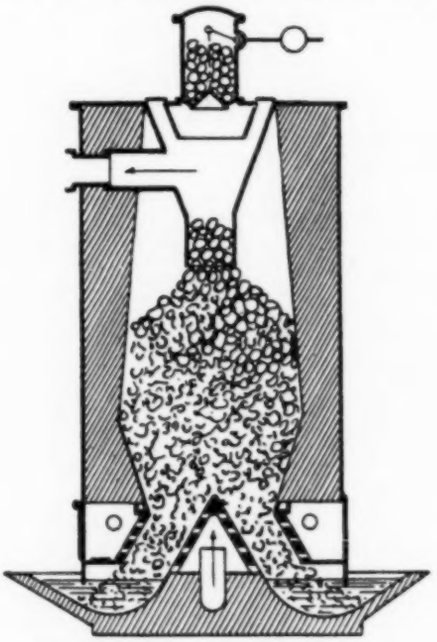


FIG. 6.—BUIRE-LENCANCHEZ PRODUCER.

produced by dry distillation. In order to prevent them from escaping during the charging of fuel, connecting channels *D* are provided between the producer *H* and the hopper. These channels are frequently provided with a movable slide. The secondary combustion air enters through tuyeres *A* after being preheated in the brickwork. It is a disadvantage that these producers depend on the chimney draft, because the latter is governed by atmospheric conditions. Hence, even in these producers artificial blast has been resorted to, which permits the use of a higher fuel bed. Fig. 3 shows this new development of the Siemens producer (four producers combined to one unit), which is very similar to the shaft type.

The use of an artificial blast for producers is almost uni-

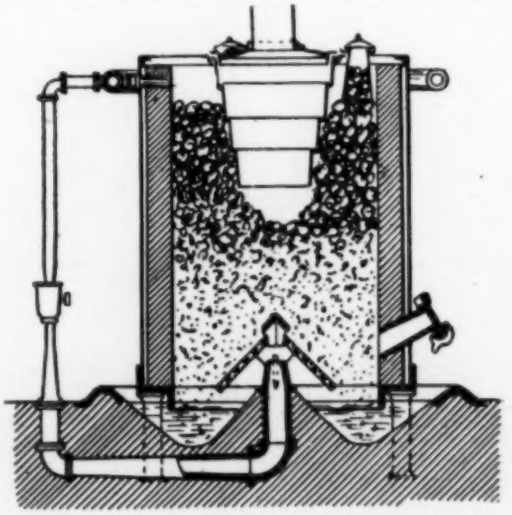


FIG. 7.—ZETZSCHE PRODUCER.

versal for heating purposes; however, considering the generation of power we find an exception in the so-called suction-gas producer plants. Here the sucking power of the piston of the gas engine is utilized for drawing the air through the producer,

the quality of gas produced being automatically regulated by the demand of the engine. As the sucking power of the latter

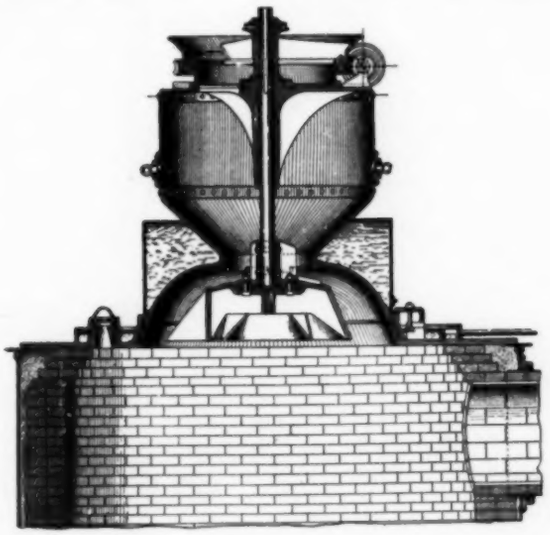


FIG. 8.—BILDT FEED.

is very large, the difficulties met with in producers with natural draft do not arise in this case.

The aim in the development of the construction of modern producers is the reduction of manual work, the production of a uniformly good gas with high efficiency, and, if possible, by a continuous operation of the producer.

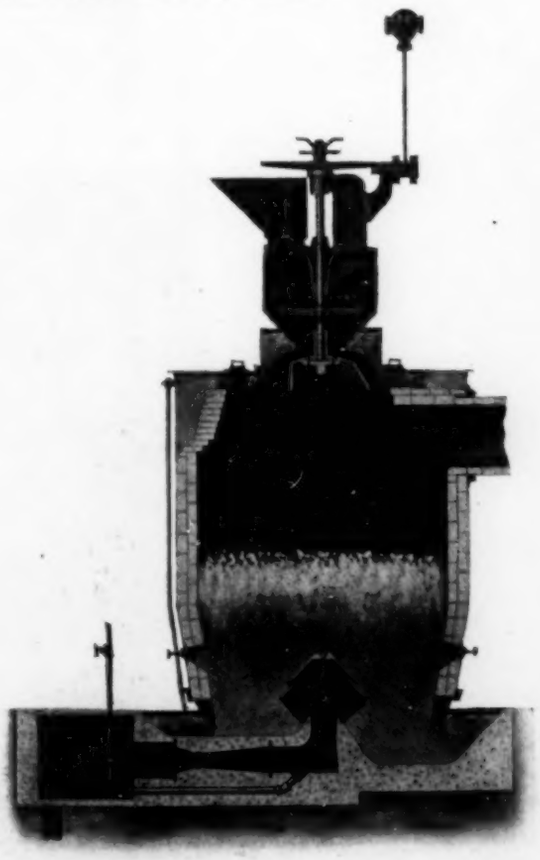


FIG. 9.—WATER-SEAL PRODUCER, WITH BILDT FEED.

The latter point is especially desirable with installations containing only one producer, while in plants comprising a number of producers an alternate disconnection for cleaning purposes is possible. If one main is supplied from several producers, the uniformity of the gas is increased.

The charging appliances of gas producers must be so arranged that the production of gas is not interfered with during the operation of charging. Hence, in producers of the draft and suction type the entrance of air has to be prevented; in pressure producers the escape of gas. This is effected by bell hoppers.

In all these hoppers the fuel to be charged is first transported to a hopper space, which is separated from the producer space proper by an air-tight bell. Then the upper door of the hopper space is closed and by opening the bell the charge is allowed to run into the producer. Fig. 4 shows such a hopper. The charging is done at certain intervals, which causes a change in the uniformity of the gas, as the dry distillation of

FIG. 10.—MORGAN PRODUCER.

the green coal is not going on uniformly. Wendt observed changes of more than 10 per cent in the thermal value of the gas when working with a producer charged with coal rich in gas. The harder the fuel, the smaller are the variations.

In order to produce a more uniform gas and to reduce the manual work, continuous charging has been tried by various ways.

The first, suggested by Ebelman, Fig. 5, in the first half of the nineteenth century, consists of the application of a charging shaft, from which the fuel gradually travels to the zone of combustion. The gas is drawn off outside the charging shaft whereby the latter assumes the temperature of the escaping gas. This causes the generation of gas already in the shaft and makes the use of a bell hopper (Fig. 4) unavoidable, except in cases where still larger quantities of fuel are kept in readiness above the charging shaft. The latter is generally made of cast iron, and is gradually destroyed if exposed to high temperatures.

In the producer of Buire-Lencanchez (Fig. 6) the gases escape through the charging shaft.

In the producer of Bleringer the fuel is charged outside around the central pipe, which serves only as gas escape.

Zetzsche has gone still further (Fig. 7) by so developing this central pipe that it can be lengthened or shortened, whereby the height of the fuel bed can be regulated according to the quality of the fuel. The lower rings of the pipe can be easily exchanged if necessary.

A second method of charging continuously employs various mechanical appliances, the first among them having been con-

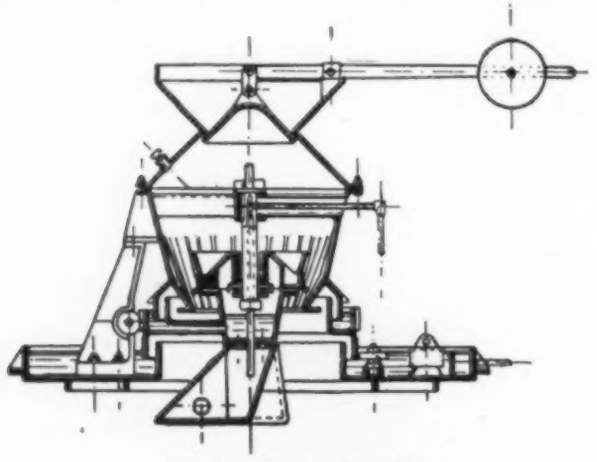


FIG. 11.—POETTER PRODUCER.

structed by Bildt (Fig. 8). A water-seal producer with Bildt feed is shown in Fig. 9.

To-day there is a considerable number of mechanical charging devices on the market. The Morgan feeder, of the Morgan Construction Company, of this country, the automatic feed of which is stated to insure almost absolute uniformity of both quantity and quality of gas produced, is shown in Figs. 10 and 20; the feeders of Poetter & Company in Figs. 11 and 12.

The Poetter producer is not provided with a double-door hopper. However, it is recommended to make an air-tight pipe connection from the hopper to the coal storage. By opening a slide the desired quantity of fuel is allowed to run into the hopper. This feed can also be made absolutely mechanical. Those parts of the feed which come in contact with the hot gases are generally water cooled. A distributor takes care of

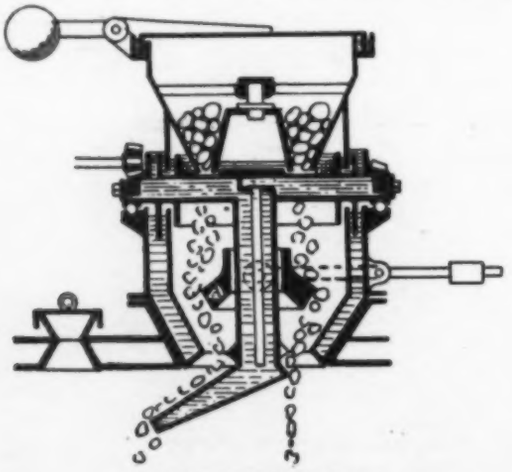


FIG. 12.—POETTER PRODUCER.

the uniform distribution of the fuel. This feature makes these constructions superior to the plain bell hoppers. However, the mechanical feed is used only for large units.

While with all producers it is of advantage to use a fuel of uniform size, this is especially important in producers which are charged mechanically. Poetter has constructed a feed for coarse coal in which he provides a crusher above the distributor.

It must not be overlooked, however, that considerable quantities of dust are produced by the action of these crushers.

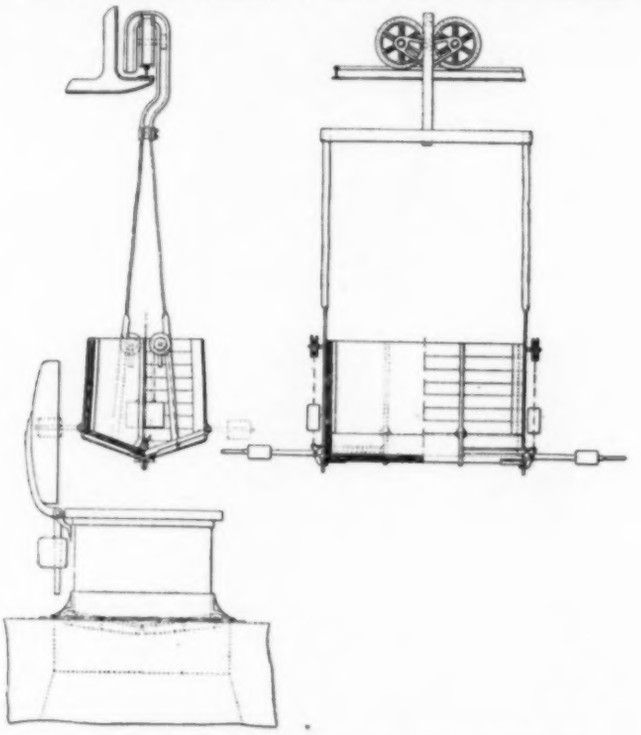


FIG. 13.—CHARGING DEVICE FOR RUSSIAN WOOD PRODUCERS.

This causes an increase of the impurities of the gas, a tight packing of the fuel and finally the formation of holes.

A charging device for Russian wood producers is shown in Fig. 13.

Another important part of the producer is the means for removing the ash and clinker. Here the aim is also to reduce the manual work and to decrease the loss of combustibles through the ash. In the old Siemens producers up to 10 per cent of the fuel was found in the ash, later producers showed a loss of 5 per cent, while in modern producers the loss is said to be reduced to 1 per cent or 1½ per cent. Further aims are the removal of clinker without discontinuing the operation of the producer and accessibility of its respective parts.

FIG. 14.—KOERTING BLOWER.

We will now say a few words regarding the blast, which is produced in all, or nearly all, plants by means of steam jet blowers, which are the most convenient appliances to that end, as they do not get out of order; furthermore, every producer is, and remains, independent with respect to the blast if the latter is produced by steam jet blowers. (For very wet fuels,

as certain grades of peat and lignite, dry blast has to be used, as is easily understood.) The steam jet blower must be properly constructed in order to produce economically the highest possible steam velocity.

Fig. 14 shows the well-known Koerting blower with spindle. *A* is the air inlet, *R* the regulating spindle, *S* the steam connection, *M* the nozzles. With ordinary bituminous or hard coals there is no difficulty to so regulate the quantity of air by means of the steam jet blower as to get dry gas. It is hardly necessary to lay stress upon the self-evident fact that the steam used in these blowers should be dry.

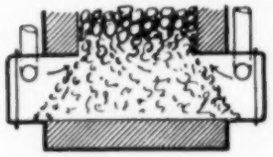


FIG. 15.—ASH-PIT.

A high-pressure blast is of no advantage in the operation of producers, as it means an unnecessary loss of energy, formation of holes and deterioration of the gas.

Returning again to the discussion of the ash-pit region, we show in Fig. 15 the ash pit of a producer without a grate. The ash rests upon a firebrick base, the air enters through the sides as shown by the arrows. In a vertical producer of considerable diameter the air will rise along the wall, the path of least resistance, whereby a dead zone is formed in the center of the shaft, causing a defective production of gas. Therefore, in large producers the diameter is frequently decreased toward the bottom.

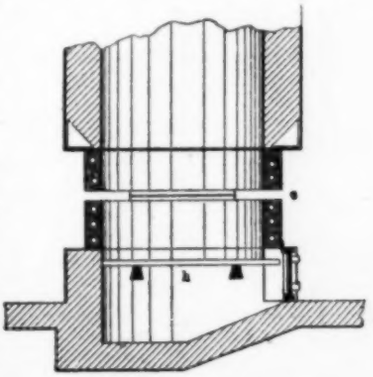


FIG. 16.—TURK'S PRODUCER.

The simple plane grate insures a uniform distribution of the air over the entire area. However, with large diameters the life of the grate is short and the removing of the clinkers a very tedious and difficult operation. Furthermore, the unburned fuel falling through these grate bars represents a considerable loss.

For facilitating the removing of the clinkers in large producers, so-called "false grates" have been resorted to, which at the period of cleansing are inserted above the ashes. In this case the gas production is stopped during cleaning. Turk's producer, which is illustrated in Fig 16, shows in slit *e* the place where the false grate is inserted above the grate *h*.

Step grates are also sometimes employed. Fig. 17 shows such an arrangement in a Turk producer. Fig. 18 illustrates a Poetter producer with so-called polygonal grate. The removal of the clinker from these producers is by no means an easy job. The loss through fuel getting into the ash is 5 per cent to 6 per cent.

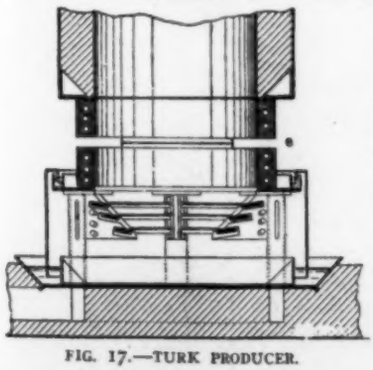


FIG. 17.—TURK PRODUCER.

Of similar construction is the producer with basket-shaped grate, which is built by Paul Schmidt and Desgras. It is mainly used for lignite briquettes. The channels for the admission of air also support the circular lower grade beam. The ashes rest in most of these constructions upon the bottom of the ash pit, which is covered with water. Sometimes also plane grates are used at the lowest point of the grate region. The Mond producer shows a similar construction around the grate.

In all these producers the clinker accumulations formed must be loosened through the grate slits. Hence the various parts have to be removable and exchangeable. In order to facilitate the removal of the clinkers, Schneefuss has proposed a shaking grate of basket shape suspended on chains.

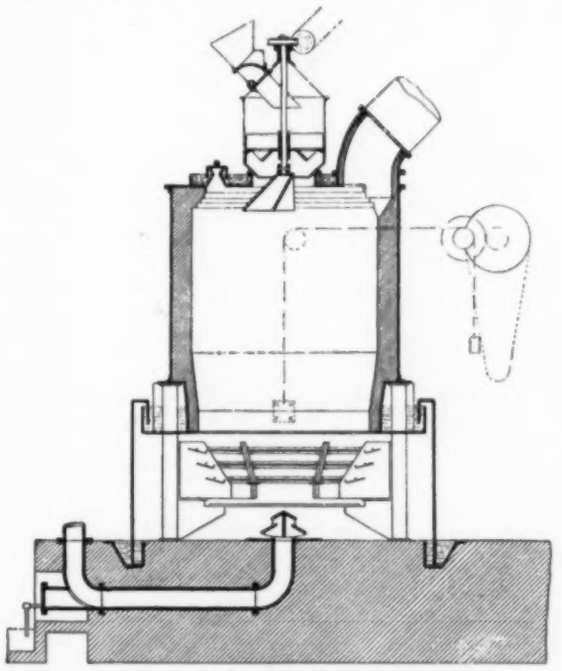


FIG. 18.—POETTER PRODUCER.

During the period of removing the clinkers, the operation must be interrupted in all these producers, as the ash doors have to be opened.

If the operation of the producers is to be continuous, the ashes and clinkers must be removed during the operation. This is effected either by a water-seal or by mechanical draft appliances. A typical producer with water seal as constructed by Poetter & Company is shown in Fig. 19. The combustion air is introduced through a central pipe. The hot bed of ashes effects a posterior combustion of carbon particles which might have escaped combustion and better distribution of the air.

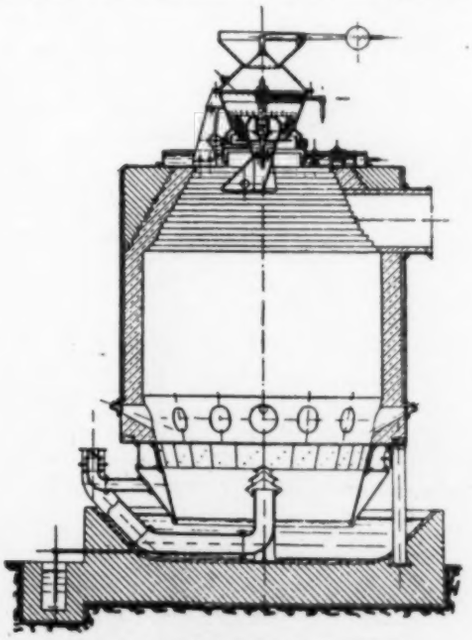


FIG. 19.—PRODUCER, WITH WATER SEAL.

In the Morgan producer (Fig. 20), which gives excellent results—the loss of fuel in the ash being reduced to 1 per cent to

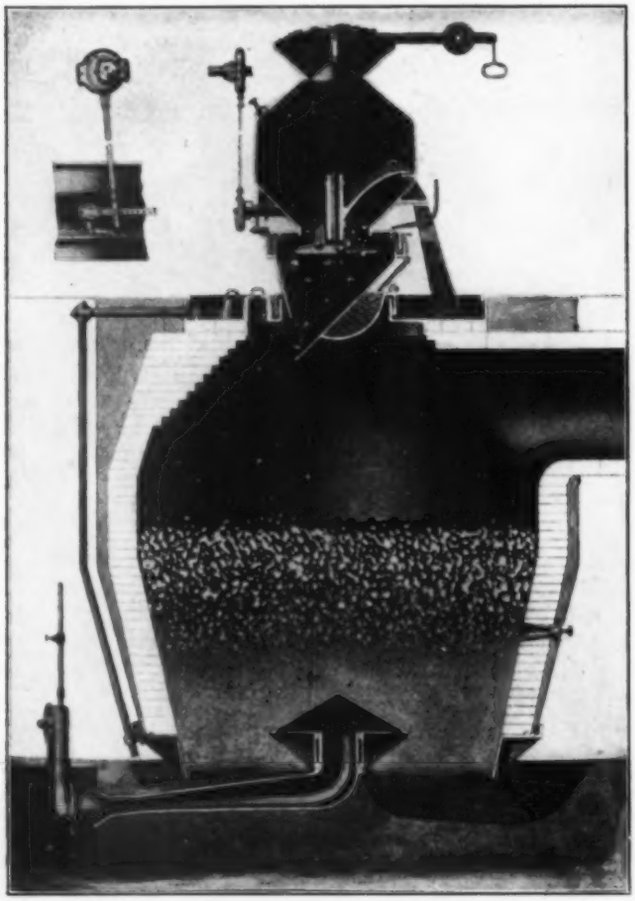


FIG. 20.—MORGAN PRODUCER.

1½ per cent—the air is introduced in the center, while Schlueter (Fig. 21) arrives at good results by introducing air at the sides through a certain number of tuyeres and by suitably re-

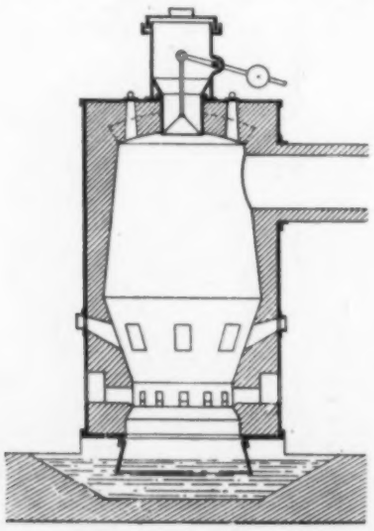


FIG. 21.—SCHLUETER PRODUCER.

ducing the diameter of the producer in the zone of combustion.

As part of the water of the seal is evaporated by the heat of the ash, the quantity of water (steam) put into these producers must be reduced. The clinkers are loosened by poke-holes in the walls. A producer of remarkable simplicity in which the removal of ash and clinkers is easily performed is the Duff process, which in the Bradley modification is shown in Fig. 22.

The special feature of this producer is the use of four blowers and four grates. It is to be stated that, while only two

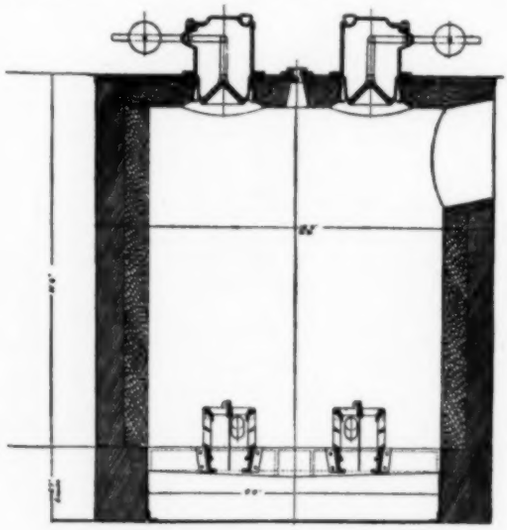


FIG. 22.—BRADLEY-DUFF PRODUCER.

grates are shown in the cut, a dividing plate is provided between each grate. This makes practically four independent grates. For instance, should the fire get too hot at either of the end walls running parallel with the grate, the blowers controlling those halves of the grates are closed down partly or entirely, as the case may require. This applies also to the center halves of the grates, which are controlled and regulated in the same manner. Hence, an excellent control of the condition of the fire is effected by the regulation of the steam and air blast.

For the removal of ashes mechanical arrangements have also

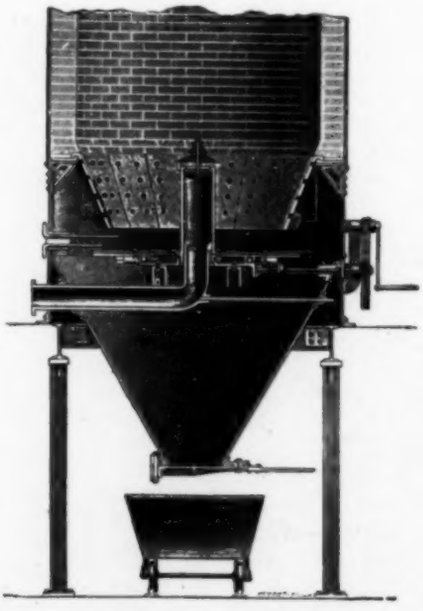


FIG. 23.—TAYLOR PRODUCER.

been constructed. The Taylor producer (Fig. 23) was among the first of this kind. In this type a solid circular bottom plate or table carries a deep bed of ashes and is arranged to revolve; the revolving of this table discharges the ash and clinker over the edge into a sealed ash pit beneath. The table is revolved

by means of a rack under the table, engaging with a pinion on a shaft driven by hand or power gearing substantially attached

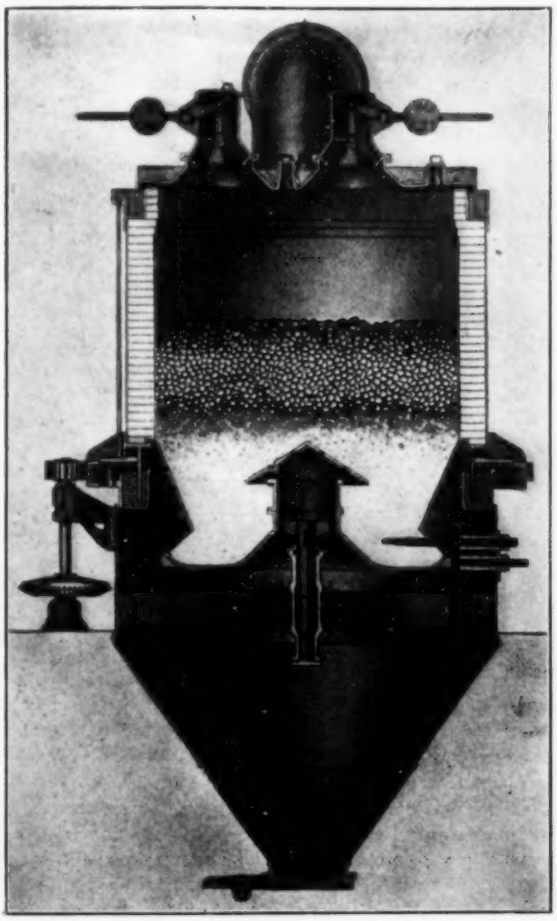


FIG. 24.—HUGHES PRODUCER.

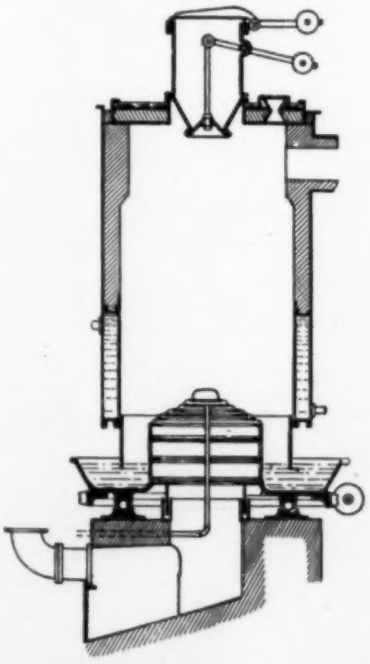


FIG. 25.—KERPELY PRODUCER.

to the outside of the lower casing. Suitable guides hold the table carefully. The grinding is done as fast as the ashes rise too far above the desired line—say, every 6 to 24 hours, or according to the rate of working. The bed of ash is kept about 3½ ft. deep on the revolving table in the larger sizes.

Another example of a self-cleaning continuous producer is the Hughes type, shown in Fig. 24. This producer is divided into two parts, the upper and the lower, with a water seal between, the upper portion rotating mechanically. By means of an iron bar, thrust between the ash table and the revolving part of the body, the clinkers are broken up and with the ashes fall into the ash receptacle beneath. By opening an outlet valve at the bottom of this cone-shaped ash receptacle the ashes are discharged into cars underneath.

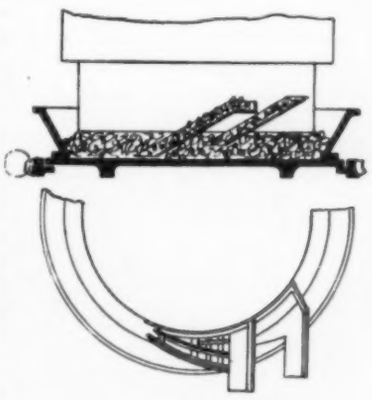


FIG. 26.—ASH REMOVAL.

The upper shell of the producer is made of steel plate riveted to and resting upon a steel ring forming a combined tread and rack. This rack is driven by a vertical shaft and pinion, connected to the main driving shaft by a train of gearing. Thus the upper shell is rotated as above mentioned. The tread of this steel rack travels on conical chilled-iron wheels having tight axles revolving in self-oiling boxes.

A further development as far as the rotation of the grate parts is concerned is the Kerpely producer, shown in Fig. 25. The rotating plate is developed as water seal and carries the grate, which consists of several plates, through which the air passes into the producer. The lower part of the grate disintegrates the clinkers and the latter are automatically removed from the water seal by means of a shovel. One rotation is made in three hours.

In the Rehmann producer the rotating part consists of suitably arranged cones, which are provided with perforations through which the air enters. The arrangement of the shovels

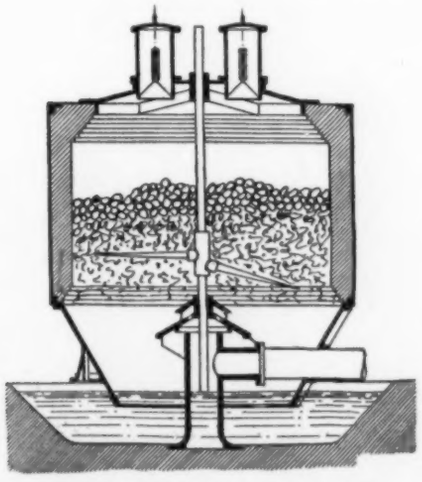


FIG. 27.—FRASER-TALBOT PRODUCER.

for removing the ash is shown in Fig. 26. The larger pieces of clinkers are raked out, the smaller ones shoveled out.

In these producers the ash is loosened and the clinker disintegrated. We will now discuss the next step—the mechanically poked producers.

The Fraser-Talbot producer (Fig. 27) pokes the fuel by means of two agitators arranged on a vertical shaft.

The latest development along these lines is the Hughes producer (Fig. 28), in which the mechanical poker is a water-

cooled steel casting suspended from a trunnion. The poker is operated by ratchet gearing actuated by a crank and crankshaft which is driven by a reduction gearing connected to the main shaft. This mechanism moves the poker back and forth, agitating and breaking up the mass of fuel and evenly distributes the coal and helps in working dowa the ashes for removal. The uniform treatment secured by the mechanical poker gives better and more uniform results as to quality, quantity and supply of gas, and reduces the cost of installa-

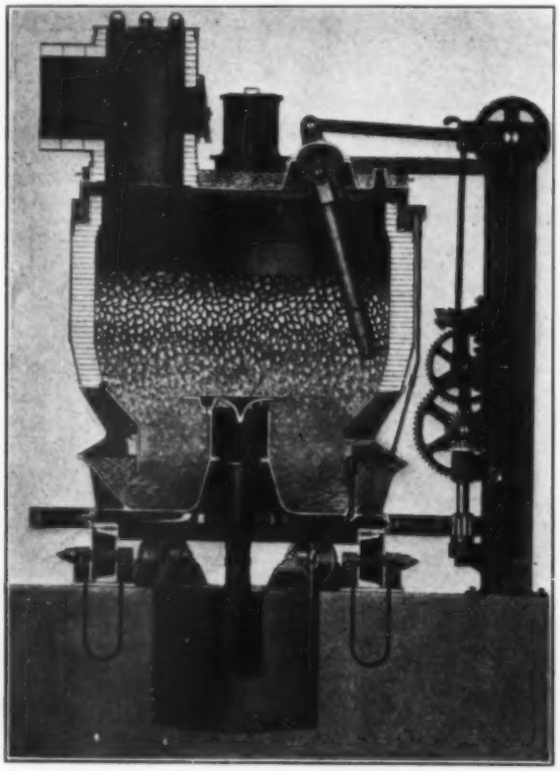


FIG. 28.—HUGHES PRODUCER.

tion and operation. The power required to operate a single producer is 3 electric hp. Twenty-five pounds of coal are gasified per square foot.

Another way for the removal of clinkers is Blesinger's device, shown in Fig. 29. In this type so-called grate cars are used for receiving ash and clinkers.

For preventing the formation of clinkers on the walls of the producer, water cooling is applied more or less successfully. In order to prevent the formation of smoke during poking, the device shown in Fig. 30 is successfully used. When the lid of a poke hole is opened, a steam cock is simultaneously opened in the turning point, steam flows over the poke hole from these points, which prevents the escape of gas.

Furnace Electrode Losses.

By Carl Hering.

It would probably surprise many who have not calculated or measured the power lost in the electrodes of electrical furnaces, to find how large it often is, and in the construction of such furnaces the question which concerns the engineer who proportions and designs the electrodes, naturally is, can this loss be reduced, and if so, how much and in what way. In many cases the chief question in the commercial success of a proposed furnace operation is the cost of the power, or more briefly, "does it pay." In some of these cases a saving of a part of these large losses in the electrodes might be enough to turn the tables, when the cost of the power is the criterion. In other cases, to the writer's knowledge, large sums of money might be saved annually by a closer approach to the best proportions of the electrodes.

It, therefore, is becoming a matter of considerable importance now to know the laws underlying the proper design of electrodes in order to realize the best proportions if it is possible and practicable, or if it is not, then at least to know how to approach them as closely as the circumstances will permit. It may often be the case that the theoretically ideal design cannot be realized, and in some cases the cost may be prohibitive;

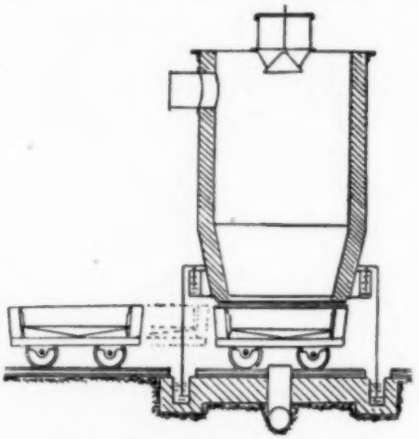


FIG. 29.—REMOVAL OF CLINKERS.

it then becomes the duty of the engineer to work out the usual problem of the limit to which an approach to the ideal conditions should be carried, or in other words, the conditions of least total cost.

It is evident that this becomes possible only when the ideal conditions are known. As long as they are not known, the designing of electrodes becomes a process of "cut and try" or in other words, more or less intelligent guessing. This process of groping around in the dark is often expensive, generally it is slow and often it is unsatisfactory, as one may be going all around the mark while being quite near it. Experiments made without a knowledge of the laws governing electrodes may give very misleading results, or the results may be improperly interpreted, or the generally dangerous process of exterpolating may lead one off the right track and to quite incorrect conclusions.

From the almost complete lack of information on this subject in text books and current literature, as also from the way in which the experimental researches have been conducted, it appears that the laws concerning the proper proportioning of such electrodes and the minimum possible losses in them, had not been determined. The writer, therefore, undertook the determination of them by an accurate and rigid analysis based

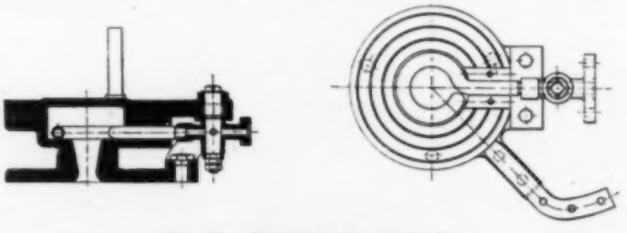


FIG. 30.—PREVENTION OF SMOKE.

on the fundamental laws of heat. The results are of considerable interest and in some respects quite surprising, as they reveal some very unsuspected relations which are of considerable importance in practice and some of which would not be likely to be accepted if it were not the fact that they can be demonstrated by a rigid analysis. They show that in some prominent cases the proportioning of the electrodes have been wide of the mark, and it is not an exaggeration to say that large sums of money could in some cases be saved annually

by changes in the electrodes, some of which are readily made while others involve more radical reconstructing. A very satisfactory result is that in many cases the ideal conditions are not hopelessly distant, but could readily be realized. The results were a good illustration of the great utility of a purely theoretical analysis, in pointing out to the designer the right path and the ideal conditions.

It is not the purpose of the present short article to give these results in detail nor the demonstrations, as they are somewhat complicated and involved, and might be improperly applied if not correctly understood. Their complete explanation would require considerable space, and involves the demonstration of a theorem in heat conduction which it is believed had not been made previously, or at least was not generally known. It is furthermore, of course, not possible to determine the best proportions, materials and losses, and to make accurate comparisons and draw definite conclusions from them in particular cases, unless the necessary fundamental physical constants and data are known, among which are the temperatures and the heat and electrical conductivites of the electrode materials at those ranges of temperatures, the heat insulation of the furnace wall surrounding the electrode, etc., which are only crudely known. It is hoped, however, that the knowledge of the correct laws of electrode losses and the importance which the reduction of those losses has in practice, will stimulate the more accurate determination of these important constants.

The writer will, therefore, limit himself here to some general results and to some comparisons and conclusions based on what seem at present to be the most likely values of the physical constants of the usual electrode materials graphite and amorphous carbon. As our present knowledge of these constants is rather crude, especially the absolute value of the heat conductivities at the high temperature ranges of electrical furnaces, the comparisons and conclusions concerning these materials may be altered somewhat when these physical constants become more accurately established.

Some of the general principles underlying the calculations of electrodes are as follows. It is evident that the larger the cross section of an electrode of given length, the greater will be the loss through it by conduction of heat from the furnace, and the less will be the electrical loss due to its resistance. The conditions are reversed when the section is constant and the length is varied. For both extremes the losses become infinite, and as they are finite in practice, there should be some proportions at which they are least.

One material may have a greater heat conductivity and a lower electrical conductivity than another, and these conductivities vary with the ranges of the temperature.

The heat in the furnace and that generated in the electrode due to its electrical resistance both originate electrically, and it is, therefore, immaterial as far as the money value of this loss is concerned whether it is more of the one kind or of the other; the total is all that concerns us here.

If both contribute to this total, how should they be added? It is customary to add them arithmetically, but is this correct?

Does the one loss affect the other?

A high heat conductivity is, as a rule, accompanied by a high electrical conductivity, hence it increases the heat loss and reduces the resistance loss; is this an advantage or otherwise?

What qualities are those which increase or decrease the total loss? Does graphite necessarily chill the furnace, as has so often been claimed, because it conducts heat so well?

Is one material intrinsically better or worse than the other, as far as the loss is concerned?

These and many other questions arise, and a proper analysis based on the fundamental laws of heat should answer them. In how far the conclusions apply to actual furnaces, of course, depends on how far it is possible or practicable to realize in practice the conditions on which the analysis is based.

Some of the general results of this anaylsis, as far as they concern all materials, are as follows:

For each electrode material there is a minimum total loss depending on the current and the temperature; it is obtained by proportioning the dimensions of the electrodes properly. Whether these best proportions can be carried out depends on the design and conditions of the particular furnace, and must, therefore, be decided by the designer. In most cases it would probably be possible, while in others it would not; in all cases it could be approached. This loss is different for different materials.

Any departure from these proportions increases the loss, hence no possible further changes of proportions can still further diminish it.

These proportions are very different for different materials, hence, if it is not possible to realize them with one material it may be possible to do so with another.

This minimum loss is smaller than is apparently generally supposed and is far less than it is in many existing furnaces. Hence considerable saving of power could be effected in many cases by a mere change of proportions, and in some cases by a change of material.

The usual method of proportioning electrodes on a basis of a fixed current density is quite incorrect and is more apt to lead one away from the desired result than toward it. It is quite as incorrect as it would be to calculate transmission wires for the least practicable loss on a basis of current density.

Comparing different materials experimentally by means of electrodes of the same size is equally incorrect and misleading; it also leads one away from the goal rather than toward it.

It is probably better to arrive at the best proportions by calculation than by experiment, provided the required physical constants are known. It is unquestionably much cheaper, quicker and simpler.

Knowing the rigidly correct relations between the various factors, it becomes possible to calculate these physical constants from the measured results of an existing case; it thus becomes possible to calculate a second design correctly, from the data obtained from a first trial.

The prevalent idea that a high heat conductivity is a very bad property of an electrode material, necessarily causing it to chill the furnace, is in part fallacious. While, of course, a low heat conductivity is in general a desirable quality of an electrode material, yet it may be actually objectionable in that it may make the proportions impracticable. There are conditions, and by no means abnormal ones, under which the writer finds that the lower heat conductivity of carbon makes the best proportions so awkward that it would not be practicable to adopt them, while with graphite with its higher heat conductivity, the proportions are easily realized. There are other cases in which the reverse is true.

Another mistaken idea is the generalization of physicists that a good electrical conductor is necessarily a good heat conductor. While this may be roughly true for the conductivities (that is, the reciprocals of the specific electrical and heat resistances), it is by no means necessarily even roughly correct for the conductances (the reciprocal of resistance as distinguished from specific resistance or resistivity), for as the writer has shown* it is quite possible to so operate an electrode that it becomes in effect a perfect heat insulator (that is, that its heat conductance is zero), although it is at the same time a good electrical conductor; and this is true irrespective of what the heat conductivity of the material may be. Thus a good conducting electrode may become even a better heat insulator than the refractory walls of a furnace. In fact, if it were possible to construct a furnace so that its walls consisted entirely of the electrodes, the curious condition could be realized of a furnace whose heat insulation is absolutely perfect. Just as a good electrical conductor may in effect be made to act as a perfect electrical insulator by means of a counter e. m. f. in the circuit, so the conductance of heat may be checked by something

*See this journal, p. 270, June, 1909. Also Transactions of the Am. Electrochem. Soc., Vol. XV, p. 300.

analogous in the form of temperature. Whether it is practicable to operate electrodes under these forced conditions, is a matter for the designing engineer to determine.

It is also a mistaken idea that the normal loss necessarily increases in proportion to the temperature, as it does not, if the electrodes are properly proportioned.

Nor does this loss necessarily increase in proportion to the heat conductivity, or diminish in proportion to the electrical conductivity. As a matter of fact, it is smaller with carbon even though its electrical resistivity is considerably greater than that of graphite, if the assumed constants are correct.

The above remarks referred to materials in general. When applied to the specific materials carbon and graphite, the comparative results, of course, depend on what the physical constants of these materials are. These have, it appears, never been accurately determined for the ranges of furnace temperatures, but from published experimental data the writer has deduced certain values which are probably not very far from the correct ones. As both carbon and graphite are artificial products, it cannot be expected that these physical properties will be the same in different lots; this is more especially true for carbon whose resistivity seems even to be very different in large electrodes from what it is in small ones, as though the baking had not penetrated to the interior. Hence conclusions based on such data will, of course, also lack accuracy. It may be of interest to say here, however, that the minimum loss in electrodes and their best proportions, do not vary in the same (or inverse) proportion as the two conductivities, but less rapidly, hence a variation or inaccuracy of say 10 per cent in the constants will change the results by less than 10 per cent.

Based on what appear to the writer to be the most probable values of these constants known at present, the following conclusions can be drawn, and it is believed that they will not be very materially altered by subsequent more accurate determinations of the constants.

The prevalent idea that graphite, on account of its higher heat conductivity, chills the furnace, is a mistake, and if it has been found to do so it is because the electrodes were improperly proportioned.

The loss of energy in graphite electrodes for the same furnace conditions (that is, temperature and current) will always be slightly greater than for carbon, when both are properly proportioned to obtain the minimum loss, but the difference is apparently only a few per cent and is therefore far less than the differences in losses due to incorrect proportioning are likely to be; it is certainly not enough to cause a noticeable chilling of the furnace. Hence the choice between carbon and graphite should be based on other considerations such as consumption, size, shape, cost, etc.

The proportions for graphite are very different from those for carbon, when both are designed for obtaining the minimum loss. In many cases the proportions for carbons become impracticable, and if they cannot be carried out the minimum loss cannot be attained, while with graphite they are possible; hence in such cases the loss for carbon could easily exceed that for graphite. The reverse is true in other cases.

Experimental comparisons between carbon and graphite electrodes of the same size are worse than useless, as they give one a false assurance. Either one or the other was then necessarily incorrectly proportioned, and is therefore tested under unfair conditions.

This minimum loss for both carbon and graphite is smaller than is apparently generally believed, and the analysis points out the directions of improvement of the physical properties by which it might be still further reduced.

If carbon electrodes for very high temperature furnaces are proportioned correctly at the start, and if during operation they become graphitized at the hot end, they will then no longer be properly proportioned and the loss will be increased. Or if improperly proportioned at the start the loss after graphitization may be less.

Such experimental data as that given by Mr. C. A. Hansen in his interesting article on Furnace Electrode Losses on p. 358 of the previous issue of this journal, are very valuable to the profession and will aid greatly in developing the proper design of electrodes. His results, as distinguished from his deductions from them, bear out the analytical researches of the writer. If his tests had been carried out with greater precision the results would have enabled the physical constants to be deduced from them. But even as they are, the constants calculated from the results agree as well as could be expected with those that the writer has deduced from other sources.

In making his deductions, however, Mr. Hansen has in some cases resorted to the always dangerous process of exterpolation or generalization, that is, applying the results to ranges beyond those of the test. While in part his deduction that the loss diminishes with increasing length of insulated electrode, agrees with the rigid analytical result, yet if he had continued his range of tests he would no doubt have found a turning point at which the loss again increases. He would also have found that under different conditions this turning point would be at an entirely different length of electrode, perhaps much shorter than his greatest length, or perhaps even still longer. Hence a general rule that electrodes should be long, is not at all correct.

His deduction that "It is apparent from the data given that the efficiency of a graphite electrode, regardless of its length, within reasonable limits, of course, increases rapidly with increasing current density" is another instance in which it is dangerous to exterpolate, for while this is true for that particular test, the writer could describe other and not at all abnormal conditions under which exactly the reverse would be true; hence it is not a general law. It may be safely stated that electrodes should not be proportioned according to current density; to do so may lead one away from rather than toward the desired end.

The statment in his last paragraph that for carbon the loss would probably increase instead of decreasing with the length, is also borne out only in part by the rigid analysis. The writer could state conditions under which the reverse would be true, and if so, it is not a general law. However, the latter case would probably be the exceptional one and the former the more usual.

Mr. Hansen seems to add the heat conduction loss to the C^2R loss to get the total. This is not correct; they do not add arithmetically in this way. The summation of these two losses is not such a simple relation.

There is a tendency among some people to discourage and even belittle what they call theoretical researches. If, however, a problem involves a large number of variables, as this one does, it is, in the writer's opinion, often far simpler, quicker, cheaper and more reliable to first work out the theoretical relations and then confirm them by experiment, than to make the experiments first and then deduce the laws from them. The number of experimental variations necessary to do the latter increases with enormous rapidity as the number of variables increases, and even then the inaccuracy of the constants and the measurements may lead one to a complicated relation when the real relation may be quite simple. Moreover in purely experimental researches the interpretation of the results and especially any exterpolation beyond the experimental range, may often lead one away from the right direction. From the results which the analytical investigation shows in this case, the writer feels sure that it would have taken very extended and expensive experimental researches to have determined the true laws of electrode losses which teach us what the best possible results are and how to design electrodes in order to approach them as closely as practicable; also to show us how each of the many variables will effect the result. In the present case these laws show not only how to design the electrodes and what limits it would be useless to try to exceed, but also how one may best select those of the original constants of the furnace itself which are open

to choice (like the relation between the volts and amperes for a given output in watts) in order to reduce the percentage which the loss in the electrodes bears to the whole, and hence increase the total efficiency of the furnace. It is possible now to calculate electrodes more accurately than the constants are known, or than it is possible to carry out the conditions in practice. This would evidently not have been the case had the laws been determined empirically.

PHILADELPIA, PA.

Influence of Arsenic and of Tin Upon the Magnetic Properties of Iron.

BY CHARLES F. BURGESS and JAMES ASTON.

It is an interesting fact of both scientific and commercial importance that pure iron is not necessarily the best iron for use in electrical machinery or apparatus where it is desirable to keep down the magnetic losses. Indeed, the addition of certain elements to this iron may greatly improve the magnetic properties. The addition of silicon has so greatly improved the materials used in transformer construction as to have given rise to what may be termed a revolution in the transformer industry.

The success in the use of silicon calls attention to what may be accomplished by the use of certain other alloying elements, and the purpose of this paper is to point out the apparent influence of arsenic and of tin, elements which, in the experiments here recorded, show a material reduction in hysteresis losses and an increase in permeability as compared with an approximately pure iron taken as a standard.

The results here given are submitted with due appreciation of the fact that methods of making magnetic tests are not sufficiently accurate or standardized to make the measurements of different observers strictly comparable. Also, that the alloys produced and upon which measurements have been made are not sufficient in number to warrant the assumption that factors other than the alloying agent may not have some influence upon the results which have been obtained.

In a paper presented at the fifteenth meeting of the American Electrochemical Society in May, 1909, the writers gave the results of observations on alloys of electrolytic iron with

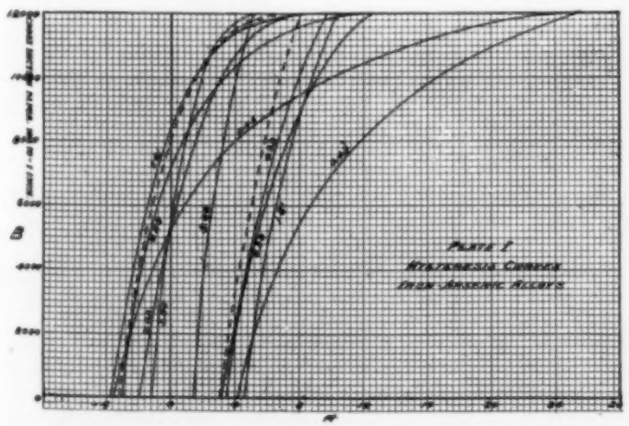


FIG. I.—HYSTERESIS CURVES. IRON-ARSENIC ALLOYS.

arsenic and bismuth in which the analyses of the electrolytic iron in the various iron alloys used are given; also the methods of preparing the samples and of conducting the tests. The data here given are an extension of this work, the results of further measurements, and a description of alloys with tin, a metal which is shown to have much the same influence on iron as has arsenic.

The magnetic tests are made with an Esterline permeameter. The alloys were prepared by melting electrolytically refined iron with different proportions of arsenic and of tin in magnesia crucibles placed inside of graphite containers and heated in an electrical resistor furnace. The ingots weighing about one pound were subsequently forged into rods and machined into bars 1 cm in diameter. These bars were tested for their magnetic properties under various heat treatments.

Check analyses have been made to determine the actual content of tin and arsenic. In the case of the arsenic the analyses checked closely with the amounts added to the crucible up to about 4 per cent, while in the case of tin there were material discrepancies between the amount added and the amount found in the resultant ingot.

As noted in the above mentioned article, the magnetic tests

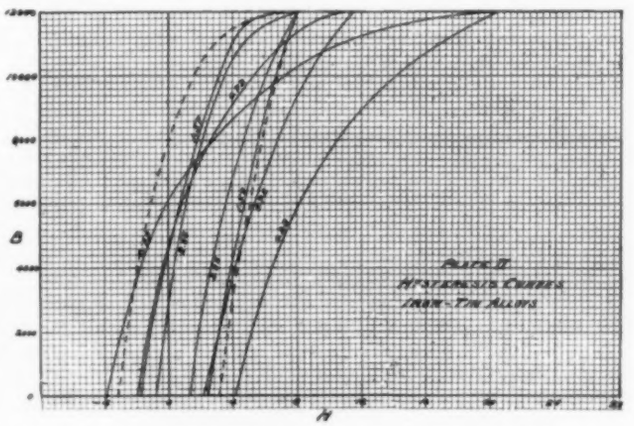


FIG. 2.—HYSTERESIS CURVES. IRON-TIN ALLOYS.

are all compared with a forged electrolytic iron sample, which is used as a standard. In the following table is given the analysis of this bar, together with the compositions of the original anode stock of Swedish iron and the resultant product after two electrolytic refinings:

Per Cent.	Anode.	Double Refined.	Electro-forged.
C	0.260	0.012	0.047
S	0.007	None	0.005
Si	0.109	0.013	0.062
P	0.007	0.004	0.016
Mn	0.021	None	None
Iron (difference)	99.971.		

As will be seen from this table, the refined material has a purity of 99.97 iron and is representative of the material used in the preparation of the alloys.

The magnetic tests were made upon all samples under four different heat treatments—first, as forged; second, after heating to 675° C. and slowly cooling; third, after heating to 1000° C. and slowly cooling; fourth, after heating to 900° C. and quenching in water. In our general series of tests the quality is indicated by a magnetization or B-H curve and by readings of the retentivity and coercive force. In this paper, since alloys of arsenic and tin are of promise mainly for transformer working, where low hysteresis loss is the governing factor, these results have been determined for a fixed value of flux density (B = 12,000) and are here plotted.

In Table I the quality of the standard is given and can be compared with the Swedish anode material, which anode stock is of a quality comparable to ordinary high grades of wrought iron. The standard reference loop for electrolytic iron is indicated in the plates as a dotted curve. It is not the best pure iron sample which we have tested, but is satisfactory as a standard in showing that if the alloys equal this material they have exceptional magnetic qualities.

Arsenic.

Tests of the iron-arsenic alloys under the four different conditions previously mentioned have been made upon the following:

Bar.	Calculated per cent arsenic.	Actual per cent arsenic.	Carbon Per Cent.
121 I	0.25	0.292	.....
121 H	0.50	0.430	.....
113 A	1.0	0.915	.....
113 B	2.0	1.810	0.042
113 D	4.0	3.862	.....
113 F	6.0	4.141	.....
113 H	10.0	3.563	.....

TABLE I—MAGNETIC TESTS DATA.

Bar	Comp. Per Cent.	H = 10 Unann'd	H = 10 Ann'd 675	H = 10 Ann'd 1000	H = 10 Quench 900	H = 20 Unann'd	H = 20 Ann'd 675	H = 20 Ann'd 1000	H = 20 Quench 900	H = 50 Unann'd	H = 50 Ann'd 675	H = 50 Ann'd 1000	H = 50 Quench 900	H = 100 Unann'd	H = 100 Ann'd 675	H = 100 Ann'd 1000	H = 100 Quench 900
Iron																	
N & W	Anode	9,500	10,000	10,850	8,400	13,200	14,200	13,900	12,050	15,700	16,500	15,850	15,550	17,450	18,000	17,200	18,150
117 A	Elec forg.	13,100	10,000	13,350	11,800	15,750	15,950	15,430	14,600	17,600	17,700	17,050	16,930	18,850	18,850	18,200	18,150
Arsenic																	
121 J	0.29	10,500	13,200	10,800	11,200	14,750	15,550	14,100	14,750	16,900	17,250	16,500	16,700	18,350	18,550	17,850	17,950
121 H	0.43	7,000	7,800	10,400	8,100	13,000	14,000	13,750	12,750	16,300	16,600	15,950	16,250	17,800	18,100	17,250	17,600
113 A	0.92	6,200	6,250	11,950	12,600	13,200	14,050	14,750	15,300	16,450	17,000	16,650	17,050	17,950	18,550	17,950	18,250
113 B	1.81	8,300	11,850	12,600	10,300	13,950	15,750	15,150	13,800	16,700	17,450	16,850	16,650	17,950	18,750	18,150	18,250
113 H	3.46	12,400	14,200	12,300	13,450	15,000	16,100	14,600	15,450	16,700	17,550	16,650	16,900	17,950	18,750	17,950	18,000
113 D	3.86	13,850	15,050	14,850	13,600	15,350	16,300	15,750	15,450	16,450	17,550	16,850	16,900	17,600	18,650	17,850	18,100
113 F	4.14	13,300	14,200	14,050	.....	15,500	15,900	15,750	.....	17,000	17,250	17,050	.....	18,200	18,450	18,150	.....
Tin																	
111 B	0.29	2,150	8,650	9,400	9,000	9,300	13,600	13,150	13,000	16,350	16,650	16,150	16,350	18,250	18,250	17,600	17,900
103 C	0.34	3,900	6,400	9,400	11,000	10,550	13,200	13,300	14,150	16,450	16,700	16,250	16,250	18,350	18,600	17,700	17,900
*103 D	0.69	5,800	7,000	11,300	13,750	12,450	13,750	14,800	15,750	16,300	16,950	16,900	17,200	18,100	18,650	18,200	18,400
111 &	0.72	9,400	11,700	11,300	14,150	13,950	15,600	15,200	16,300	17,500	17,900	17,350	17,550	19,250	19,200	18,500	18,700
111 A	1.57	8,700	11,700	14,000	14,350	13,300	15,200	15,750	15,550	16,500	17,100	17,150	16,700	18,050	18,400	18,300	17,600
121 J	2.06	12,900	12,400	13,350	13,750	14,750	15,200	15,000	15,350	16,200	16,750	16,250	16,450	17,250	17,950	17,400	17,500

In addition, later tests have been made upon bars of added arsenic content of 1, 3 and 5 per cent, but analyses have not been made to confirm these percentages. Although the arsenic was supposed to be present up to 10 per cent, analysis shows 4.141 per cent as the maximum, seemingly the saturation point under the conditions of our melt. Below this percentage the arsenic is taken up by the iron in about the added proportions.

The material formed sound ingots and forged easily throughout. The bars were readily machined, but were brittle for the higher arsenic content. The alliaceous odor was very evident upon the slightest heating, being very intense during forging and readily detected even upon slight heating, due to grinding. Data of the magnetic tests are given in Tables I and II and typical curves are plotted in Plate I. The higher densities are in general reached after the annealing at 675°, while the minimum hysteresis losses at low magnetizing forces are obtained by annealing at the higher temperature of 1000°.

The hysteresis curves, however, are plotted for a fixed maximum density of 12,000 lines per square centimeter, after the last heat treatment, the quenching at 900° C. This heat treatment in reality amounts to an additional annealing, since no hardening was observed, due no doubt to the absence of carbon in the alloy. This can be seen by inspection of Table II, where the coercive forces become successively lower, even after quenching.

Nothing of particular interest is brought out in the alloys of low arsenic content. Those with a very low percentage of arsenic lie close to the electrolytic standard; with additional arsenic there is a falling off in quality. The most interesting features are noted with the iron-arsenic content of 3.86 per cent, 4.14 per cent and 3.56 per cent. Very high flux densities are reached for small impressed fields, especially after annealing, where these arsenic alloys are equal to the electrolytic material for values of H above 50 and are considerably superior below, thus ranking with the best material for which records are available.

The value as magnetic material is more clearly brought out in the hysteresis loops plotted in Plate I and the data given in Table III. There is a marked decrease in the area of the loop (which is representative of the hysteresis loss per magnetic cycle for the bar) with a high arsenic percentage of 3.86. Relative areas compared with the electrolytic standard as unity are 1.08 and 1.26, for arsenic 0.29 per cent and 0.43, respectively; this area falling off to 0.56, with arsenic 3.56 per cent, and to 0.39 for the bar with 3.86 per cent arsenic.

In our previous paper we recorded also the effect of the addition of arsenic to ordinary iron. A good grade of transformer sheet steel was melted into ingots alone and with an addition of 5 per cent of arsenic, then forged and turned into test bars. The result was a marked improvement in the magnetic quality, due to the addition of the arsenic. The effect was particularly pronounced for the lower magnetizing forces.

Tin.

A number of alloys of iron and tin were tested, of which the following six were analyzed and form the basis of this discussion:

Bar.	Per Cent Tin. Added.	Per Cent Tin. Analysis.	Per Cent Carbon.
111 B	0.2	0.288	.....
103 C	0.5	0.342	.....
103 D	1.0	0.068	0.095
111 &	2.0	0.717	.....
111 A	3.0	1.568	.....
121 J	4.0	2.059	.....

This series is somewhat analogous to the iron-arsenic series in that the volatilization point of the tin is reached before the fusing point of the iron. The analyses show that a considerable amount of the tin has been lost (about 50 per cent), but that there is still a large percentage remaining and that the bars have a resultant tin content varying in the order of the added amounts.

The data of the magnetic tests are given in Tables I and II, and representative results are plotted in Plate I. The hysteresis loops are again those obtained after quenching at 900° C.

As in the arsenic series, we note nothing of particular interest in the alloys with lower percentages of tin. They are comparable to the electrolytic standard. The real value is indicated in the hysteresis data where there is to be noted a perceptible falling off in the loss with the increase of tin. This loss is especially low in the alloys of highest tin content of 1.57 per cent and 2.06 per cent, where the relative areas are 0.67 and 0.40, respectively, compared with the standard as unity.

Comparisons.

Magnetic testing is not on such a basis that data from various sources can be taken as absolute, and on this account comparisons are apt to be misleading. Recognizing this fact, we have endeavored to make our comparisons more exact by collecting samples of commercial material and testing this upon our own apparatus. In Plate III and Table III are given the results of tests upon representative samples of high-grade materials, including silicon steels from several manufacturers and users. AM is a very pure commercial iron (99.88-Fe). AP and M are silicon sheet steels for transformer service. F is an electrical sheet steel, composition unknown.

At this place it may be well to mention that we have also made alloys of iron and silicon and our results are analogous to those of commercial silicon sheets. Our material, of course, differs essentially in being a binary alloy, practically free from the other elements usually met in practice.

In addition to the column in Table III showing the relative hysteresis losses by means

TABLE II—COERCIVE FORCE AND RETENTIVITY.

Bar Iron	Comp. Per Cent.	H (Max) = 200 Coercive Force				H (Max) = 200 Retentivity			
		Unann'd	Ann'd 675	Ann'd 1000	Quench 900	Unann'd	Ann'd 675	Ann'd 1000	Quench 900
N S W	Anode	5.5	4.8	3.9	5.0	11,400	12,700	9,000	8,500
117 A	Elec forged	5.5	6.2	5.1	2.5	12,300	13,800	10,000	8,000
ARSENIC.									
121 I	0.29	6.5	5.5	4.5	4.0	12,400	14,600	9,900	10,800
121 H	0.43	8.2	8.0	5.5	4.3	12,700	12,700	9,400	8,600
113 A	0.92	9.5	9.2	5.3	3.0	12,700	14,700	12,300	9,500
113 B	1.81	5.9	5.0	3.7	3.0	10,300	12,200	8,900	8,600
113 H	3.56	4.5	4.0	2.7	2.7	11,000	13,400	8,600	8,900
113 D	3.86	4.0	3.5	2.0	2.1	12,100	13,000	6,500	8,600
113 F	4.14	5.0	3.3	2.3	..	10,800	12,300	8,900	.....
TIN.									
111 B	0.29	23.5	7.5	5.3	5.0	12,100	11,700	9,100	8,700
103 C	0.34	12.3	8.9	5.5	3.6	12,300	12,700	9,400	8,600
103 D	0.69	7.5	7.7	4.3	3.7	8,000	12,300	10,400	12,100
111 &	0.72	7.0	5.7	3.9	2.9	11,000	13,200	8,700	8,900
111 A	1.57	6.0	4.0	4.0	3.3	10,000	13,100	11,900	10,800
121 J	2.06	3.0	4.3	3.5	2.5	8,100	11,300	9,300	8,600

of the integrated areas of the loops, we have added a column designed "relative value," and in which we have endeavored to represent the values of the materials for transformer working more consistently than is done by taking into account the hysteresis losses alone. For example, in Table III, in integration of the loops for electrolytic and Swedish iron at the same working density of B = 12,000, the hysteresis loss for the latter is 0.94, compared to electrolytic material as unity. But to reach this density the Swedish iron requires a magnetizing

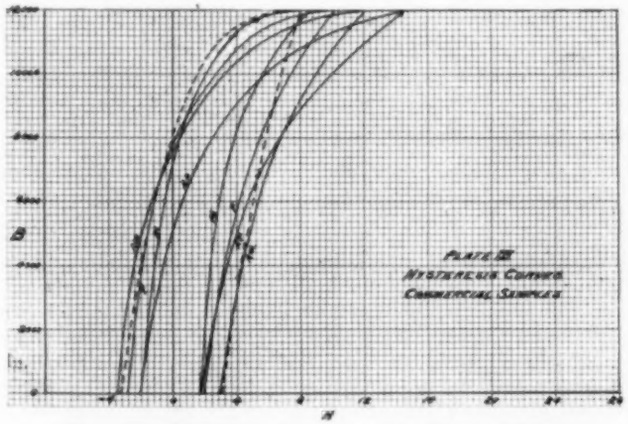


FIG. 3.—HYSTERESIS CURVES. COMMERCIAL SAMPLES.

force of 13 and electrolytic iron but 8. Evidently, therefore, the greater number of turns necessary, together with the increased length of magnetic circuit required to give space for this extra winding, makes Swedish material of lower grade.

To take into account these various factors we find that a

TABLE III—RELATIVE HYSTERESIS LOSSES.

Bar.	Comp. %	Loop Area in².	Relative Area.	B(Max) = 12000 H(Max).	Relative Value.
IRON.					
N S W	Anode	8.14	0.94	13.0	1.49
117 A	Elec forged	8.65	1.0	8.0	1.0
ARSENIC.					
121 I	0.29	9.36	1.08	12.7	1.67
121 H	0.43	10.90	1.26	25.4	3.90
113 A	0.92	7.41	0.86	9.8	1.01
113 B	1.81	11.61	1.34	10.5	1.72
113 H	3.56	4.88	0.56	6.2	0.43
113 D	3.86	3.37	0.39	5.1	0.24
TIN.					
111 B	0.29	11.42	1.32	20.2	3.26
103 C	0.34	9.59	1.11	20.5	2.77
103 D	0.69	8.00	0.93	10.5	1.19
111 &	0.72	6.09	0.70	11.5	0.99
111 A	1.57	5.86	0.67	8.1	0.67
121 J	2.06	3.46	0.40	8.1	0.40
COMMERCIAL.					
F	Sheet steel	7.25	0.84	10.2	1.22
A P	Silicon sheet	5.77	0.67	14.7	1.20
M	Silicon sheet	5.20	0.60	8.7	0.64
A M	High purity iron	9.18	1.06	12.0	1.55

very fair approximation of the value is obtained by making the comparison on the basis of the relative products of the loop area, times the magnetizing force required to reach the fixed density of B = 12,000 per sq. cm. These figures, compared to the standard electrolytic bar as unity, are plotted in the column "relative value."

Examination of the above table shows several materials with lower hysteresis losses than the electrolytic standard. Among these are a number of commercial samples; and of the alloys we note those of high arsenic and high tin content. The materials having the very lowest losses are the two bars of highest percentages of arsenic and tin. These comparative figures are better shown in the column of relative values, where, as discussed above, there is taken into account also the magnetizing force required to reach the maximum density of 12,000 lines per sq. cm.

The addition to iron of arsenic and tin has the desirable effect noted with silicon, viz., an increase of the electrical resistance with a consequent reduction of eddy current losses. Should further investigation show ageing qualities comparable to those of the silicon alloys, these iron-arsenic and iron-tin alloys are worthy of attention for transformer working in view of the evident low hysteresis and high permeability.

The above results were obtained as a part of a more extended investigation carried on under a grant of the Carnegie Institution, of Washington.

Chemical Engineering Laboratories,
University of Wisconsin.

Notes on Electrochemistry and Metallurgy in Great Britain.

(From Our London Correspondent.)

Iron and Steel Institute.

Continuing the discussion on Mr. Rodenhauser's paper on **electric steel furnaces,** the first part of which was recorded in our last issue, Prof. Turner said that with direct current electrolytic action might decompose phosphide and sulphide. He considered that induction furnaces were not suitable because they did not attain a sufficiently high temperature.

Mr. F. Moorwood thought the induction furnace did not lend itself to handiwork, and that the resistance furnace was better adapted to the existing steel-works plant and to more ready handling by the workmen. The electric furnace should now pass out of the hands of the electrician into those of the steel maker.

Mr. E. Adamson said the author seemed to suggest that the steel made in the Héroult furnace was not so homogeneous as that produced by the Roechling-Rodenhauser plant. Speaking from his practical experience he could say that steel made in a Héroult furnace was quite homogeneous, and he quoted analytical results in support.

Mr. A. Cooper said he had seen the furnaces at work and brought away samples of the steel, which gave results corroborating the analyses given by the author; but the metal being used was not from a Bessemer converter, but from a basic Bessemer converter. Consequently, there were two distinct processes of manufacture. He thought that, for rail steel, until metal was taken from the blast furnace or from the mixer, the electric furnace could not become a serious competitor with the open-hearth process. In Middlesbrough it was easy to make steel of the same composition as that given by the author with 0.004 per cent of sulphur and 0.023 per cent of phosphorus by

the basic open-hearth process. He was associated with a works at which 30,000 tons of rails had been made which were capable of withstanding the test stated by the author.

Mr. T. Rowlands gave details of an induction furnace demonstration plant at Niagara. Steel containing 1.2 per cent of carbon had been melted with a consumption of 440 kw-hours per ton. In another instance ferro-manganese was melted with 520 kw-hours per ton, and the figure for manganese steel was 600 kw-hours per ton. Pure iron had also been melted, with addition of silicon in the ladle, for making selected steel.

Mr. Frick, with reference to the temperature question, said they had attained from 1650 deg. C. to 1700 deg. C. His remarks on the removal of slag had reference to his own type of furnace only.

Mr. Rodenhauser, in reply, said he had not been able to follow all the questions in the discussion, and would make a deferred written communication. Steel rails of higher resistance were made in the electric furnace with an expenditure of about 100 kw-hours per ton, but at this low figure it was not possible to make steel of a high degree of purity. There was no difficulty in attaining any required temperature in the induction furnace, and they were now working a three-phase furnace in which any requisite temperature was obtained.

* * *

Dr. M. Ekenberg's paper on **"fuel from peat"** followed.

Mr. J. E. Stead said he could vouch for the accuracy of the author's statements bearing on the chemistry of the process. More than 20 years ago he had investigated a scheme for smelting iron with peat, and found that the heat evolved was only sufficient to vaporize the associated water; and, therefore, if peat were to be produced in a dry state it must be air and sun dried. Dr. Ekenberg's discovery had made the recovery of peat fuel possible. Pressure alone did not squeeze out the water, but by the simple process of heating under pressure to 200 deg. C. the hydrocellulose was altered in character and could be separated from the water by filtration. He believed that this process would render available as a source of power the vast mass of fuel in the peat bogs.

Mr. Andrew Lamberton said the paper had reference to the steps designed to avert waste of material, and if the author's process effected what was claimed for it, then the matter was of the greatest importance to the institute.

Dr. Ekenberg replied. Some acid was formed in the process of heating, but the iron tubes did not corrode to a greater extent than would be represented by a depreciation of 10 per cent.

The discussion on **"A heat-treatment study of Bessemer steels,"** by Professor McWilliam and Ernest J. Barnes, was opened by Mr. W. Beardshaw, who remarked that when he became president of the Sheffield Society of Engineers and Metallurgists they presented a Brayshaw furnace to the university, and that paper was the first outcome of that presentation. It was desirable that experiments should be made on a larger scale. He had made many tests on samples up to 6 in. in diameter. In a bar of large diameter he found that the core and the exterior gave different results; on the outside the ultimate stress was 48 tons, the yield point was 32 tons, and the extension in 2 in. was 23 per cent. In the core the ultimate stress was 44 tons, the yield point 27½ tons, and extension identical. On a 1½-in. square bar the ultimate stress was 49 tons, the yield point 38 tons, and extension 33 per cent.

Mr. J. Gledhill agreed that experiments on larger pieces would be useful. Professor McWilliam's experiments were academical, and we wanted to know more about heat treatment of masses. Over-annealing lowered the tensile strength, but increased the resistance to shock. Material of a durable nature with increased elastic limits was a desideratum.

Mr. Stead asked whether alternating tests had been applied at Sheffield on cross-sections of plates and bars. He found that in alternating bend tests stresses in one direction are double those taken in another (longitudinal and cross). The alternating bend test indicated the direction of the rolling. He would like to see microphotographs. Striation occurred in every steel containing less than 0.04 per cent of carbon. Such steels might be condemned, but were perfectly good. Manganese sulphide was associated with high phosphorus.

Professor McWilliam, in his brief reply, pointed out that his experiments on 1-in. bars were not entirely academical. Much practical work was done with bars of these dimensions.

A New Calorimeter.

At a recent meeting of the Physical Society Dr. C. V. Drysdale exhibited the new thermo-electric calorimeter of Féry, which can be used without intermission and gives the heat-producing value of gas at any required instant. The gas to be tested is burned under constant pressure in a special burner at rates varying from 5 liters to 10 liters per hour. The incandescent gas heats the hot junction of a thermopile, while the air supply traverses the cold junction. The thermopile has 15 pairs, and can give an e.m.f. of 0.2 volt, which is sufficient to work a recorder, as in the case of the Richard thermograph and barograph.

Market Prices, July 30th.

Tin.—Starting at £131 10 0 fluctuated between this price and £129 18 0 twice during the first fortnight, becoming steadier on the 14th and finally rising to £132 15 0.

Copper.—Has kept fairly steady for this metal between £58 and £59, becoming harder in the middle of the month, but finally falling to £58 12 6 (July 29).

English Lead.—Dropped slightly on the 7th; since steady at £12 or a little over, rising to £13 on the 21st; final price (29th) £12 18 9.

Iron Cleveland Warrants.—Commenced at 47/-, rose to 48/- on the 18th and finished at 48/9½.

Scotch Pig.—Was steady at 53/- till the 20th, when rose, finishing at 54/10½.

Hematite.—Dropped badly from 56/- to 52/10 on the 13th., recovered sharply and remains at 56/6.

Antimony, black sulphide powder, per ton	£25	0	0
Sulphate of ammonia, f.o.b. Liverpool	11	2	6
Copper sulphate	18	17	6
Caustic soda, white, 77 per cent	11	2	6
Bleaching powder, 35 per cent	4	5	0
Shellac, standard T. N., orange spots, cwt	3	10	0
Carbolic acid, liquid, 97 to 99 per cent, gallon			10½
Creosote, ordinary good liquid, gallon			2½
Naphtha solvent, 90 per cent at 160 deg. C., gallon			8
Rubber, Para, fine, pound		8	3
Platinum, per ounce	4	11	6

RECENT METALLURGICAL AND ELECTROCHEMICAL PATENTS

Smelting of Titaniferous Iron Ores.—The object of a new process of Prof. W. Borchers is the treatment of a titaniferous iron ore for the production of pig iron containing the silicon but not titanium. The titanium passes into the slag and this slag is directly used as the reducing agent for fresh quantities of ore. Limestone or any other fluxes forming fluxes are rendered superfluous. The inventor proceeds as follows: On putting the plant for the first time into operation, titaniferous iron ore or titaniferous iron sand is put into a suitable electric furnace and carbon is added, whereupon the contents of the furnace are smelted. Later on, when the plant is in its regular working condition, a deoxidizing agent, more fully to be described below, is added at a temperature lying near but not much above 2000 deg. C., in quantities sufficient to extract the main bulk of the iron and all of the silicon present. The resulting smelting products are a crude iron which contains practically the whole amount of the silicon of the ores, and a slag which contains a small part of iron, but very much titanic acid. For

the success of this operation, it is necessary, however, that the quantity of silica (SiO_2) of the ore is not as large as in the poorer kinds of titaniferous iron sands, of which it sometimes forms 20 per cent and more. In such cases a magnetic dressing of the ore would easily produce concentrates with but very few per cents (1.5 to 3 per cent) of silica, which can be easily reduced according to the present process. For complete separation of the titanic acid by means of this smelting operation the quantity of the deoxidizing agent must be so chosen that with every 10 to 15 parts by weight of the titanium present one part by weight of iron will go into the slag. Lime or other fluxes are not used in this process.

After a sufficient quantity of slag has collected—eventually after repeated tapping of the crude iron which contains the reduced silicon, so that the necessary steps can be taken to put the slag to its proper use—the slag will be electrically heated either in the same furnace after the crude iron has been drawn off, or in another furnace to a higher temperature, estimated to exceed 2500 deg. C. Then carbon in the shape of coke, charcoal and the like is added in a heated condition and the slag is now reduced to a product which principally consists of iron, titanium, and carbon, which product must be considered as a mixture of carbides, titanides, and variable amounts of free titanium. This mixture forms an energetic reducing agent, which is employed as such for reducing the titaniferous ore, in the place of coal or coke hitherto used for this purpose.

The characteristics of the present invention therefore reside in the following facts: 1. Reducing iron ores rich in titanium to crude iron which contains silicon and is free from titanium, and a slag poor in silicon and rich in titanium. 2. Transforming this slag without a previous cooling off through a comparatively little increase in temperature by means of carbon into a highly reactive reducing agent. 3. Utilization of the reducing agent obtained according to point 2 for the purpose of reducing the ore according to point 1 as much as this process demands, and utilization of an eventual over-production of such reducing agent for other metallurgical operations. (930,344. Aug. 10, 1909.)

Precipitation of Copper from Solutions.—To precipitate metallic copper from a copper sulphate solution, L. Jumau, subjects it to a high temperature under pressure in the presence of sulphurous acid, produced in the previous roasting process. The copper is precipitated from the solution in the form of pure metallic copper, and the sulphurous acid is oxidized to sulphuric acid, according to the equation

$$CuSO_4 + SO_2 + 2H_2O = Cu + 2H_2SO_4$$

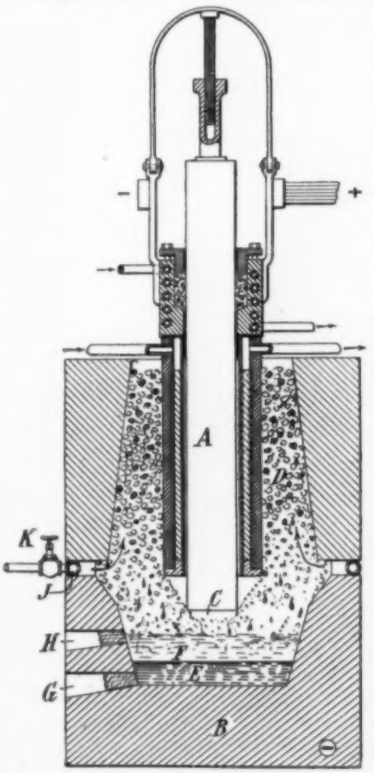
The percentage of copper precipitated increases as the temperature is raised.

Temperatures.	Copper Precipitated.
140°C	47 per cent
155°C	62 per cent
167°C	65 per cent
190°C	79 per cent

To avoid an excessive pressure due to the high temperature necessary, the inventor employs only that quantity of sulphurous acid which is theoretically required without attaining saturation and then heats the whole gradually. Or he first heats the solution without sulphurous acid, and then introduces the latter as gas under pressure, adding gradually only the theoretical quantity. (930,967, Aug. 10, 1909.)

In a modification of this method, also due to L. Jumau, the solution is subjected to a high temperature in the presence of wood in any form, such as saw-dust, shavings, waste wood and the like. This process is particularly advantageous when the ores do not contain sulphur, as no sulphurous acid is then furnished by a previous roasting process. The solution thus treated yields metallic copper, and, as product of decomposition of the wood, organic acids and carbon dioxide that can be absorbed by putting the apparatus in which the solution is heated under pressure, into communication with a space filled with some absorbent of carbon dioxide, such as lime; however, the carbon dioxide may escape freely through the valve of the digester. (930,968, Aug. 10, 1909.)

Electric Smelting Furnace for Copper Ores.—In the usual process of treating copper ores, the ore is smelted to obtain a matte of copper sulphide and iron sulphide, while the silicates and other impurities which constitute the gangue are eliminated. The percentage of copper in the matte may vary from 30 to 60. The matte is then subjected to a converter process by which the iron and most of the sulphur is burned out, leaving black copper approximately 90 per cent pure. Dr. P. L. T. Heroult proposes an electric-furnace process which permits perfect regulation of the heat on one hand and regulation of the consumption of iron and sulphur on the other hand, so that a black copper or a rich matte may be obtained without special difficulty, and directly from ores of widely varying compositions. The process consists in feeding the ore into an electric furnace and fusing it by electric heat, and simultaneously injecting oxygen into the ore for the oxidation of the iron and sulphur. The advantage of this process is the separation of the step of oxidizing the iron and sulphur from the step of fusing. The fusing, on the other hand, is affected without oxidation. Therefore a wide range of operations may be effected with perfect accuracy, ranging from mere fusion without any oxidation of impurities on one hand to complete oxidation of the iron and sulphur on the other hand. In above figure current enters through the electrode *A* and passes out through the body *B* of the furnace. The arc is indicated by *C* and the zone of fusion by the drops of molten material. The ore *D* is introduced at the top of the furnace and is gradually fed down through the zone of fusion, the resulting product forming in a pool *E* at the bottom of the furnace, with a layer of slab *F* floating thereon. The desired product *E* and the slag *F* are drawn off at desired intervals through tap holes *G* and *H*. The air is introduced through an annular pipe *J* above the zone of fusion, and mingles thoroughly with the ore, rising through the same and effecting the reduction described. A valve, indicated typically at *K*, determines the pressure or quantity of air injected. (930,666, Aug. 10, 1909.)



COPPER SMELTING FURNACE.

Treatment of Slimes in Electrolytic Lead Refineries.—Hitherto slime produced in electrolytic lead refineries, working on the Betts process, has always been collected with considerable trouble, and washed to recover the lead depositing electrolyte contained in it before being submitted to chemical or metallurgical treatment, and even then there is a loss of lead-depositing electrolyte. A simpler and more rational treatment of the slimes has now been worked out by Mr. Anson G. Betts. He has found that he can dissolve both the antimony and lead in the slime, as well as copper, silver and arsenic, if desired, by the use of a solution containing an acid making a soluble lead salt,

e. g. fluosilicic acid and also hydrofluoric acid in moderate quantity. A solution of lead fluosilicate and fluosilicic acid containing 5 to 6 per cent lead and 15 per cent SiF_6 ion permits the addition to it of as much as 5 per cent, anhydrous HF at a moderate temperature, and considerably more at an elevated temperature. Such a solution containing 5 per cent HF is capable of dissolving 10 per cent antimony as trifluoride, and a solution of antimony trifluoride even in large proportions will not precipitate lead fluoride from a lead solution, as the addition of most fluorides—for example, sodium fluoride—will do. Betts prefers to use, then, to take the metals of the slime into solution, a liquid containing considerable fluosilicic acid, and a moderate quantity of hydrofluoric acid. Lead peroxide used in connection with fluosilicic, or other equivalent acid, will not cause metallic lead, copper, etc., to go into solution as fluosilicicates, etc., but will also cause antimony to go into solution as fluoride, if hydrofluoric acid is present in a moderate proportion.

As the solution becomes more neutral, the precipitating power for lead of the hydrofluoric acid becomes greater, from the increasing proportion of lead to be precipitated, and the decreasing proportion of fluosilicic acid remaining to tend to dissolve any lead fluoride formed. However, the proportion of hydrofluoric acid becomes less as antimony trifluoride is being forced, so no lead fluoride is precipitated. Similar changes take place in a reverse direction in the preferred method of electrolyzing the solution described below. Lead peroxide is a powerful oxidizing agent, sufficiently so to cause the formation of silver salts from metallic silver, so it is possible to dissolve practically all of such metals of the slime as copper, lead, antimony, tin, silver and certain amounts of bismuth. To quicken the reaction, Betts grinds the lead peroxide finely.

In the practical execution of his process, Betts proceeds as follows: The lead anodes are suspended in a tank in the usual way with the usual cathodes, and the whole electrolyzed until the anodes are pretty well dissolved. By suitable means, below or after siphoning the clear solution out of the tank, the slime is caused to drop from the anodes to the bottom of the tank. After removing the scrap he then adds about the theoretical amount of peroxide necessary to carry out the following reactions:

$$Pb + PbO_2 + 2H_2SiF_6 = 2PbSiF_6 + 2H_2O$$
$$Cu + PbO_2 + 2H_2SiF_6 = PbSiF_6 + CuSiF_6$$
$$2Ag + PbO_2 + 2H_2SiF_6 = Ag_2SiF_6 + PbSiF_6 + 2H_2O$$
$$2Bi + 3PbO_2 + 6HF + 3H_2SiF_6 = 2BiF_3 + 3PbSiF_6 + 6H_2O$$
$$2As + 3PbO_2 + 3H_2SiF_6 = As_2O_3 + 3PbSiF_6 + 3H_2O$$
$$2Sb + 3PbO_2 + 6HF + 3H_2SiF_6 = 2SbF_3 + 3PbSiF_6 + 6H_2O$$
$$Sn + 2PbO_2 + 4HF + 2H_2SiF_6 = SnF_4 + 2H_2SiF_6 + 4H_2O$$

The reactions with bismuth and tin are of minor importance, as these elements are usually absent or occur in relatively small quantities. The tank is nearly filled with strong H_2SiF_6 solution containing some lead which may have the composition SiF_6 ion 20 per cent, lead ¼ per cent, HF 1 to 2 per cent, and stirred preferably until solution is practically complete, or until the slime gets so thin from the solution of its antimony that it can readily be drawn off, which it is difficult to do with most raw slimes, on account of their heavy nature. The tank is finally cleaned out and used to refine more lead. After action is practically complete, the solution, which may contain about 2 per cent antimony, 0.6 per cent arsenic, 1 per cent silver, 1 per cent copper, 18 per cent lead, and perhaps 0.1 per cent bismuth, the figures, of course subject to great variation, is filtered from gold, and undissolved silver, and lead peroxide.

The solution containing the various metals of the slime is led through the tanks in which are suspended copper plates, to precipitate out metallic silver. It then passes through a series of electrolytic tanks provided with carbon anodes and suitable cathodes, copper being good for some or all and lead for others, in which a current density is used varying from 5 to 10 or more amperes per square foot with an electromotive force of from 2.2 to 2.5 volts per cell. Electrolytic copper is deposited on the first cathodes, and continues to deposit until copper is reduced to, say, 0.1 to 0.2 per cent, when a solid alloy of copper and antimony deposits further on in the series of cells, and then impure lead and then fairly pure lead. Lead peroxide is deposited on the anodes throughout, so that only one anode product is obtained, which is ground and returned to be used in slime treatment.

The cathode deposits are better than expected and are quite satisfactory mechanically. The impure cathodes are worked up by using them as anodes in a refinery cell, in a series of tanks through which the solution from the slime treatment passes. For example, the copper-antimony cathodes are used as anode, and refined by the solution as it comes from the silver precipitation, copper and antimony going into solution together while pure copper deposits. In this way a certain amount of these cathodes are always on hand, but do not accumulate faster than they are worked up. The lead peroxide precipitates as a very hard, smooth conducting coating which warps slightly and drops off the anodes occasionally, or can be easily split off. More solution is obtained than was started with, as slime contained some to start with. Part of the solution should be partially neutralized by treatment with lead peroxide and lead, according to the reaction

$$Pb + PbO_2 + 2H_2SiF_6 = 2PbSiF_6,$$

and, after being passed through a special electrolytic lead refining cell with lead anodes and cathodes for the sake of removing any traces of impurities, passed back to the lead depositing plant. (918,647, April 20, 1909.)

SYNOPSIS OF PERIODICAL LITERATURE.

Thermo-Electric Pyrometer.—In *La Lumière Electrique*, July 31, H. Pecheux describes the calibration of a copper-nickel thermoelement with the aid of a platinum, platinum-iridium couple. He finds that the copper-nickel couple may be usefully employed in the temperature range from 0 deg. C. to 920 deg. C. Within this range the e.m.f. increases in three different ways, namely, first, from 0 deg. to 235 deg., with an increasing temperature coefficient of the e.m.f., from 235 deg. to 390 deg. with a decreasing temperature coefficient, while from 390 deg. to 290 deg. the temperature coefficient again increases. For the couple calibrated by the author the law of the change of e.m.f. E with temperature t in degrees Centigrade is given by the following three equations:

(0 deg. to 235 deg.) $E = 24.38\,t + 0.0078\,t^2$
(235 deg. to 390 deg.) $E = 2124 + 43.50\,t - 0.035\,t^2$
(390 deg. to 920 deg.) $E = 7033 - 2.10\,t + 0.023\,t^2$

Boiling Points of Metals.—An approximate determination of the boiling points of metals, carried out at the University of Manchester, is described by H. C. Greenwood in a paper read before the Royal Society on May 27. The author employed a vertical carbon-tube resistance furnace, in which was suspended a long graphite crucible which contained the metal under investigation. Temperature readings of the outer walls of the crucible were taken by means of the Wanner optical pyrometer. The measurements of the boiling points were carried out by slowly raising the temperature of the crucible and observing the surface of the metal from above through an absorbing glass. At first the surface of the molten metal remains perfectly still, but as the boiling point is approached, a slight agitation of the surface is observed, which soon becomes vigorous. In the case of most of the metals studied the difference between the temperature, indicated when a gentle agitation is first apparent and that at which the ebullition has become so violent that globules of metal are being ejected from the crucible, does not exceed 100 deg. C. By taking the boiling point as that temperature at which ebullition becomes decided, quite concordant results were obtained in different experiments. Very great difficulties were encountered in boiling-point determinations of metals which

readily carburize. The remedy was to "brasque" carbon crucibles with highly shrunk pure magnesia. The following are the approximate boiling points found by the author:

	Deg.		Deg.
Aluminium	1800	Lead	1525
Antimony	1440	Magnesium	1120
Bismuth	1420	Manganese	1900
Chromium	2200	Silver	1955
Copper	2310	Tin	2270
Iron	2450		

Zinc Box White Precipitates.—In the August issue of the *Western Chemist and Metallurgist* Roy F. Coolidge gives an investigation of zinc box white precipitates. After a review of the subject he describes the analysis and treatment of white precipitates from Kendall, Mont. Zinc is the principal element and is present as hydroxide. "This is formed by the action of decomposed water on the zinc. The water is decomposed by the electromotive force developed by the zinc-gold couple." $Zn + 2H_2O = fn\,(OH)_2 + 2H$. Calcium, iron, aluminium, and magnesium are found in small quantities in the white precipitates. The gold present is mechanically mixed with the precipitates. The objections to the white precipitates are many and in one year's time they add greatly to the cost of operation. The white precipitate is quite soluble in KCN solution, and since increasing the mill solution to 3 lb. KCN per ton of solution with 1 lb. protective alkalinity, the Kendall mill is now troubled very little with white precipitate.

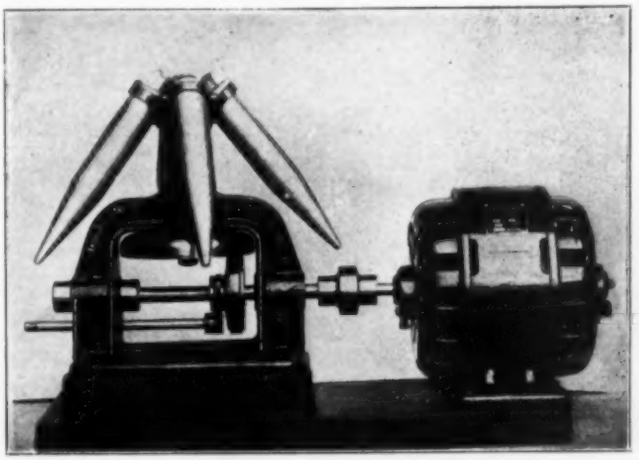
Electrochemical Industries.—The August issue of *La Houille Blanche* contains a paper by Octave Dony-Henault and C. Gall on the present status of electrochemistry and its applications. They first discuss the production of oxygen and hydrogen by electrolysis of water and note other methods for producing hydrogen (hydrolithe or calcium hydrate; decomposition of water by aluminium) and oxygen (oxylithe or compressed sodium peroxide; oxone or fused sodium peroxide; oxygenite or a mixture of infusorial earth and potassium perchlorate, with a small amount of charcoal). The authors then deal briefly with ozone, chlorine, bromine, sulphur, selenium, and tellurium, and then discuss at greater length the fixation of atmospheric nitrogen. After some remarks on the preparation of ammonia and electrolytic transformations of nitrogen compounds, they deal with the production of nitrogen oxide by electric discharges through air. They point out the reversibility of the reaction of $N + O = NO$, and the necessity of cooling quickly a gas mixture containing NO, in order to prevent its decomposition. The authors then deal more briefly with the production of phosphorus in the electric furnace, and arsenic, antimony, and tin, some remarks being made on detinning tin scrap. They then take up coron, silicon, calcium carbide and cyanamide. The article is to be continued.

Centrifuge.

Mixtures of liquids of different specific gravities or liquids containing sediments may be separated in the course of time by the simple process of settling under the force of gravity. But if the liquid be viscous the separation must be carried out quickly in order to make an analysis without delay; some greater force than gravity must be called into play. This is most conveniently supplied by rapidly rotating the materials at a high speed, setting up tremendous centrifugal forces.

In the Braun motor-driven "centrifuge," which, as shown in the accompanying illustration, consists of pivoted receptacles mounted to rotate about a vertical axis, the speed reaches more than 1500 revolutions per minute. Under these conditions the pound mass of the centrifuge tube exerts a centrifugal pull of about 320 lb., so that a sort of artificial gravity is produced 320 times as strong as the force of gravity. Since when in use the containers swing out horizontally the centrifugal force on the material in their extreme tips is about twice that at the center of gravity of the containers. Accordingly separations can be made with this apparatus in a very short time, while the adjustable speed friction drive enables the tubes to be started gradually and brought up to any desired speed.

The little motor shown, a ¼-hp Type A Westinghouse, is direct-connected to the friction-wheel shaft, which communicates its motion to the face wheel, giving a range of 1000 to 2000 revolutions per minute. The glass container tubes are surrounded by water and enclosed in an aluminium case, furnishing a cushioning surface which prevents breakage. The tubes contain 100 cu. cm. and are calibrated to tenths of a cubic centimeter, so that the results are easily and quickly read off. The motor-driven centrifuge is of recurring use in the laboratory and is almost an absolute necessity in the separation of heavy, thick, viscous liquids, such as crude oils, etc. The Braun centrifuge is manufactured by F. W. Braun, Los Angeles, Cal.



MOTOR-DRIVEN CENTRIFUGE.

Waste-Heat Air Heater.

Many operations in chemical and metallurgical engineering involve the transfer of heat between metal surfaces and fluids. Such transfer is involved in the operation of steam boilers, closed feed-water heaters, heating coils and radiators, economizers, condensers, evaporators, cooking kettles, etc. The rate of heat transference attainable obviously influences the design of these several apparatuses to a marked degree.

This rate may be expressed commercially as the number of British thermal units transferred per square foot of heating surface per hour per degree of difference of temperature and is usually designated by U. The magnitude of U is obviously affected by the following factors: first, the temperature, nature and condition of motion of the medium from which the heat is being transmitted; second, the thickness, material and condition of the intervening plate or tube surface; and, third, the temperature, nature and condition of motion of the fluid which is being heated. How great the influence of these several factors is upon the activity of the heat-transmitting surface will be apparent from an approximate statement of the values obtained in several different kinds of apparatus.

For boilers and economizers the value of U appears to vary between 2 and 3½ heat units per square foot per hour per degree difference of temperature. In heat exchangers, that is, appliances in which heat is transferred from one liquid to another through a metal surface, values of 50 to 60 are given for U. In closed feed-water heaters it is usually between 200 and 300, while in certain modern types of surface condensers values approaching 1000 are being obtained. Such a wide range of values cannot but cause the engineer to ask whether or not the performance of any one particular type of apparatus is at

the maximum possible or can be improved by changes in design or in methods of operation. In this article we shall describe some experiments made with this point in view upon the Green waste-heat air heater, a device for heating air directly from gases of combustion and similar in its general arangement to the Green fuel economizer.

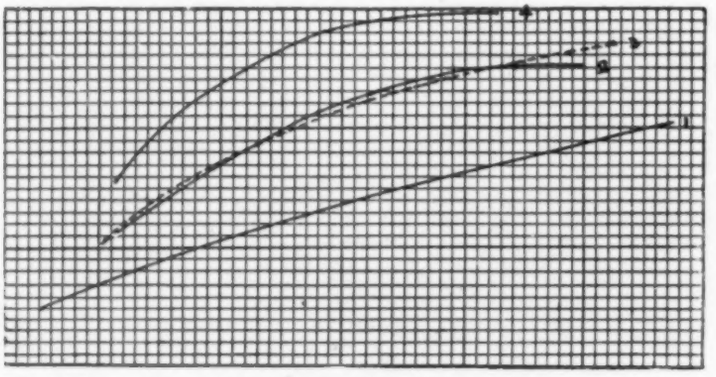


FIG. 1.—RELATION BETWEEN CUBIC FEET OF AIR PER PIPE PER MINUTE (ABSCISSAS) AND HEAT TRANSMITTED (ORDINATES).

It should be noted that whether air be heated in this device or by the ordinary means of steam coils, the source of the heat and its final destination are the same in each case. Where steam is used the heat is first transmitted from hot gases of combustion to the metal of the boiler, thence to the water and steam in the boiler, and again from the water or steam to the metal of the heating coil or radiator and, finally, to the air. In the present device the heat is transmitted from hot gases to the walls of the metal pipes and from these immediately to the air. With the same difference in temperature between the hot gases of combustion and the air, the capacity of the waste-heat air heater would undoubtedly be greater than the capacity of twice the amount of combined boiler surface and radiator surface, other conditions being equal. However, the heater is more usually employed for recovering heat from gases of combustion after the latter have already done service in a steam boiler or other apparatus. That is, the heater is usually employed as a means of fuel economy, saving the waste heat that would otherwise escape through the chimney to atmosphere and applying it to purposes for which steam would otherwise be required, or using it to preheat the air supplied to the furnace, thus increasing the temperature and efficiency of the latter.

In consequence of receiving gases at a lower temperature, the total amount of heat transmitted per square foot of surface is usually not as great as in a boiler, although the activity of the surface as measured by the number of heat units transferred per square foot per hour per degree difference of temperature is greater, particularly when the apparatus is operated with the special appliances herein described. As compared with a steam heater coil or radiator, the activity of the waste-heat air heater is comparatively high, due to the greater range of temperature, for, while an exhaust steam-heated radiator will rarely have a temperature much higher than 212 deg. Fahr. to 220 deg. Fahr., or a live steam heated radiator higher than 400 deg. Fahr., the waste-heat air heater may be receiving gases of a temperature of 1000 deg. Fahr., or higher, as for instance, the stack valve gases of water-gas generators or the waste gases from metal furnaces. When the apparatus is installed to receive the chimney flue gases from a steam boiler, the temperature will, as a rule, be between 500 deg. Fahr. and 650 deg. Fahr. The final temperature of the air heated by the apparatus will be determined by the use that is to be made of it. For heating and ventilating rooms in buildings this will be quite moderate, while for drying work it will be limited, as a rule, by the nature of the material being dried, although temperatures above 500 deg. Fahr. or 600 deg. Fahr. are sometimes employed.

The apparatus can be so connected up that the air will be passed through all the pipes in parallel or through groups placed in series. In the latter case it is customary to have the air enter the apparatus at the cold end—that is, the end from which the gases of combustion are leaving, and to leave the apparatus from the hot end, that is, the end with which the gases of combustion first come in contact, as by this means the greatest average difference in temperature is maintained throughout the apparatus. A perfect apparatus arranged in this way would be able to transfer all the heat of the hot gases to the cold gases. In making arrangements of this kind it was discovered that if the same number of cubic feet of air were put through the heater with one-half of the pipes arranged in series with the other half, the amount of heat transmitted per square foot of surface per hour per degree difference of temperature was increased 50 per cent to 75 per cent. This confirms results obtained by the engineers of the United States Geological Survey and by other investigators upon steam boilers. It appears that the transfer of heat to and from a gas is almost entirely by convection, so that anything that is done to increase the commotion or to increase the rate at which the cold gas is removed from the surface and hot gas substituted will increase the rate of heat transmission. If motion is not given to the gas mechanically or by natural gravity circulation, the transfer of heat can only take place by diffusion (conduction), which may be conceived of as a process of gas molecules receiving high velocity from the hot plate and expending it upon slower moving molecules a little distance away from the plate, these in turn passing it on to others. The transfer of heat through gases by diffusion is an exceedingly slow process, as witness the many engineering appliances in which heat insulation is secured by means of "dead-air" spaces.

The success obtained from merely increasing the velocity of the air blowing through the pipe naturally led to the suggestion that the rate of heat transference could be still more increased if the air were churned up and the cold core gas in the center of the pipe brought more positively into contact with the walls. To this end, specially designed "winged' spirals were inserted in

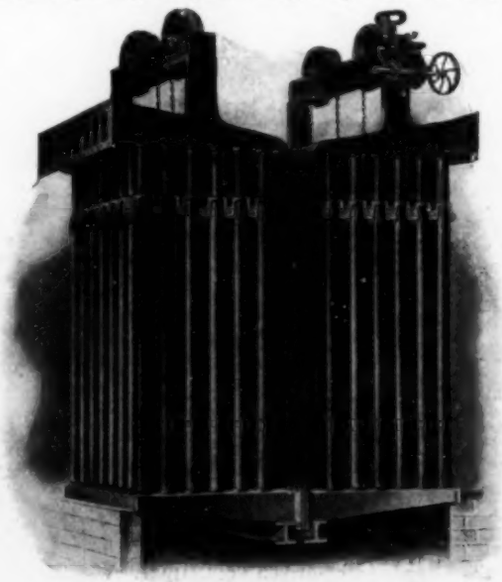


FIG. 2.—96-TUBE AIR HEATER.

the pipe, with results wholly justifying the reasoning, for the rate of heat transfer was increased in about the same ratio as by doubling the velocity of the air.

The results of these experiments are shown in the several curves in Fig. 1, where the line marked 1 shows the heat transmitted per square foot per hour per degree difference of

temperature for various numbers of cubic feet of air passed through the heater per minute. Curve No. 2 shows the same values for the same heater with the same volume of air passed first through one-half and then through the other half of the tubes in series. Curve No. 3 shows the values obtained by passing the air through all the tubes in parallel, but with winged

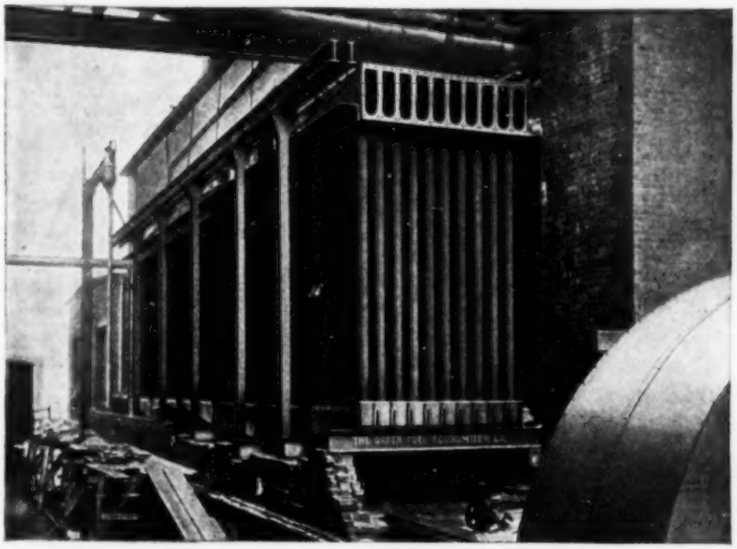


FIG 3.—GREEN WASTE HEAT AIR HEATER FOR DRYING WORK, 600 PIPES ARRANGED IN THREE PASSES.

spirals in the tubes, while No. 4 shows the values obtained with the spirals and the two groups of tubes in series. Curve 1 in this diagram is especially interesting, since it is nearly a straight line, showing that the rate of heat transmission increases almost directly as the velocity of the air, a result which had already been demonstrated by the United States Geological Sur-

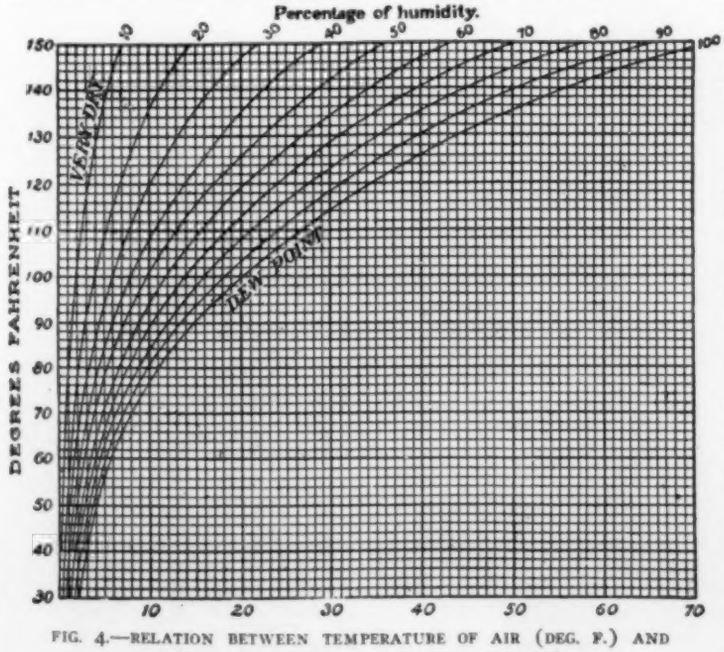


FIG. 4.—RELATION BETWEEN TEMPERATURE OF AIR (DEG. F.) AND GRAINS OF MOISTURE IN AIR PER CUBIC FOOT.

vey. In all these experiments the exteriors of the pipes were kept free of soot by means of automatic scrapers similar to those used on the economizer.

For the above information and the accompanying illustrations we are indebted to the builders of the device, the Green Fuel Economizer Company, of Matteawan, N. Y.

Purification of Water by Ozone.

Dr. S. RIDEAL read recently a paper on the purification of water by ozone before the Royal Sanitary Institute in London.

In view of the bad condition of drinking water in many cities in this country, the subject is interesting.

We take from the London *Electrician* of July 9 the following extracts:

The paper deals especially with the operation of the De Frise-Siemens installation for the sterilization of water by ozone at the St. Maur municipal water works of the city of Paris. These municipal water works draw water from the River Marne, a stream which receives a considerable amount of sewage pollution above the intake. This water after being subjected to filtration is further sterilized by ozone.

The plant consists of an efficient arrangement for the production of ozonized air and for its intimate admixture with the water. The current is generated by means of a 45-hp steam engine and a Mordey 110-volt alternator and the voltage is raised by a transformer to 4000 volts. The ozonizers are of the Siemens-Halske type, placed in a dark, cool room.

In Dr. Rideal's experiments there were six of these ozonizers running. The electrical energy required for the production of the ozone averaged 1.31 kw-hours per 104 cu. m. of water sterilized, equal to 57 kw-hours per million gallons. In addition, the energy required for compression, 1.675 kw-hours per 100 cu. m., must be added to the cost, giving a total of 133 kw-hours per million gallons.

M. Colmet Daage, the chief engineer to the Paris municipality, taking 0.11 franc (2.2 cents) as the price per kw-hour (being that charged by the Société de l'Est Parisien), estimates the average cost of treatment at 0.0184 franc (0.37 cent) per cubic meter. He further estimates that for treatment of 300 cu. m. at an electrical cost of 0.055 franc per unit, the expense would only be 0.0072 franc per cubic meter, say two-thirds of a cent per 1000 gal., excluding interest, amortization and repairs.

The ozonized air was introduced laterally into the stream of filtered water in a proportion which was kept constant throughout the run, the volume of filtered water being 104 cu. m. per hour, equal to 22,880 gal., and that of the ozonized air 42 cu. m. per hour (1483 cu. ft.) so that the volume of ozonized air supplied averaged 40.4 per cent of the volume of filtered water treated.

The water and air are drawn together by means of an injector into the bottom of a sterilizing tower. This is a vertical cylinder of enameled cast iron constructed in sections and divided at regular intervals by horizontal diaphragms consisting of carefully leveled and finely perforated trays made of celluloid with holes 0.7 mm. (0.026 in.) diameter, whereby the ascending current of gas and water is intimately mixed. In addition the height of the column is sufficient to make the air and water meet under an extra pressure of from 10 lb. to 15 lb. per square inch, which facilitates the absorption of the ozone. The columns are provided at intervals with small glass windows for inspection and with cocks for collecting samples.

The sterilizing effects of this treatment are in every way satisfactory, and it is stated that the Paris municipality has decided to ozonize the whole of its Marne supply at St. Maur, equal to 90,000 cu. m. per day. The water to be treated will pass through the existing filters at twice the present rate, 16 ft. instead of 8 ft. per 24 hours. An ozone installation capa-

ble of treating 10,000,000 gal. a day (half the above quantity) by the system described in this paper will be erected at St. Maur, involving no further delay for storage or filters. The whole of the water passing through the filters, whatever its coli content, will be ozonized at an expenditure of 315 kw-hours per million gallons.

The author's general conclusions are "that (1) the ozone treatment of filtered river water as carried out at St. Maur, Paris, by the De Frise process is a satisfactory method of insuring a standard of purification for a municipal water supply equal to modern requirements. (2) The De Frise process differs from all previous attempts at water sterilization by means of ozone in combining the De Frise sterilizer and ozone recuperation system with the Siemens-De Frise ozonizer, which combination avoids the difficulties attending the use of the emulsifiers and sprayers which have been hitherto used for this purpose and is attended with a low cost for renewals owing to breakages in the dielectric.

Portable Electric Pyrometer.

The Wm. H. Bristol electric pyrometers have become well known in many processes where temperatures lower than 2000 deg. are used. These pyrometers have been made in both switchboard and portable form to indicate or record high temperatures, but most of the instruments now in service are for ranges of temperature lower than 2000 deg. Fahr. There are quite a number of processes in which excessively high temperatures are used and these temperatures should be measured intermittently in order to make control possible and to obtain a uniform product. In experimental work temperatures in the neighborhood of 2500 deg. Fahr. should often be measured, as for instance in boiler tests where the boiler furnace temperature is to be determined.

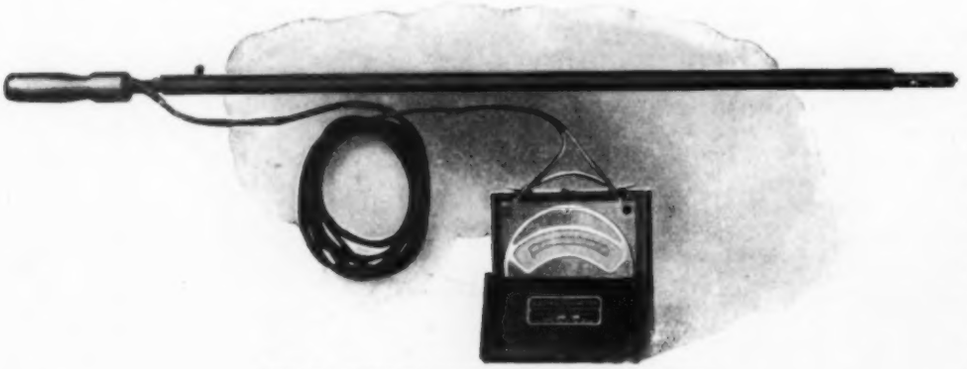


FIG. 1.—PORTABLE THERMO-ELECTRIC PYROMETER.

A new quick-reading form of the Wm. H. Bristol pyrometers has been designed and preliminary models tested in actual service in several different processes where the temperatures are excessively high and the requirements very severe. This special pyrometer consists of a patented compound thermo-electric couple used in connection with a special portable instrument equipped with a pivot jewel-bearing Weston movement. The complete outfit is shown in Fig. 1.

The thermo-electric couple is shown externally in Fig. 2. Fig. 1 shows the couple with the protecting sheath pulled back against a stop leaving the tip of the thermo-couple exposed. When a reading is to be taken with this special thermo-couple it is inserted into the furnace or kiln, as shown in Fig. 2, with the tip protected from mechanical injury and as soon as the couple has been inserted at the proper point in the kiln the iron pipe protecting sheath is slipped back so that the tip is exposed to the hot gases whose temperature is to be measured. After a reading has been taken the couple should be quickly withdrawn and partially cooled off before another reading is taken.

This form of couple is the invention of Prof. Wm. H. Bristol, formerly of Stevens Institute and now president of the Bristol Company. United States patents were issued July 5, 1904, and August 29, 1905. The compound construction of this couple is shown in Fig. 3. The point *A* corresponds to the regular junction of an ordinary thermo-couple and the two elements which join at the point *A* are platinum and platinum-rhodium, this being the particular couple selected as a standard by the German Reichsanstalt. The platinum, platinum-rhodium elements extend to the points *B* and *C*, where they are welded to two other wires made of inexpensive alloys which are such that the electro-motive forces generated at *B* and *C* are practically equal and opposed when these junctions are both exposed to temperatures not higher than 1200 deg. Fahr. These inexpensive alloy elements are extended to the point *D*, which is the cold end of the couple.

FIG. 2.—THERMO ELECTRIC COUPLE.

This construction of the quick-reading couple is such that the platinum-rhodium tip of the couple *A* may be exposed to excessively high temperatures up to 3000 deg. Fahr. without the temperature of the junctions *B* and *C* exceeding a safe limit. The temperature at *A* may be quickly measured with this special couple as the platinum-rhodium tip is exposed directly to the hot gases in furnace or kiln. In this way an inexpensive substitute is provided for the expensive platinum-rhodium couples previously employed for the measurement of such high temperatures.

This quick-reading form of the Wm. H. Bristol electric pyrometers with the compound couple has been tested under very severe conditions and found extremely valuable for such applications as brick kiln temperatures, boiler-furnace fire-box temperatures, by-product coke-oven combustion flue temperatures, soaking pit temperatures, etc. The complete outfit is portable and readings of temperatures in the neighborhood of 2500 deg. Fahr. may be obtained in a very few seconds after inserting the tip of the couple to the point where the temperature is to be measured. By using a special form of the platinum, platinum-rhodium tip this type of thermo-couple can be used to measure the temperature of red hot surfaces of metal or other material.

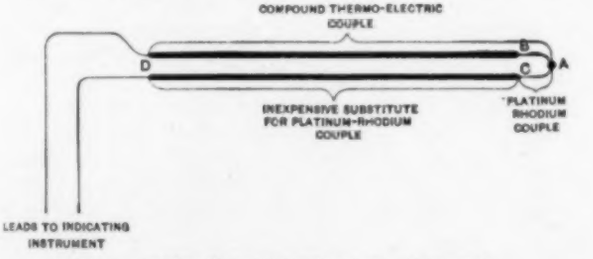


FIG. 3.—COMPOUND CONSTRUCTION OF COUPLE.

Notes.

Dr. **John E. Teeple,** consulting chemist and chemical engineer, Hudson Terminal, 50 Chuch Street, New York, announces his complete recovery from the illness which has interrupted his work for several months.

The **Crocker-Wheeler Co.** announce that on or about Sept. 10 they will open an office in the Ford Building, Detroit, Mich., in charge of Mr. Charles W. Cross.

Mr. **Wm. H. Lindsey,** of Nashville, Tenn., has been elected vice-president of the Napier Iron Works, the Crescent Coal Company and the Dealers' Fuel Company. Mr. Lindsey is prominently identified with the American Cyanamide Company and large water-power interests in the South.

Metal Corrosion and Protection.—The Carnegie Library of Pittsburgh has sent us the second revised and enlarged edition of their list of references to books and magazine articles on metal corrosion and protection. This is a very useful work. The price is 10 cents, postpaid.

Iron and Steel Institute.—The autumn meeting will be held in London from Sept. 27 to Oct. 1.

American Electrochemical Society.—The autumn meeting will be held in New York from Oct. 28 to 30.

Fixation of Atmospheric Nitrogen.—With respect to the question of working dilute nitrogen oxide gases into a more concentrated marketable product, we notice the recent (British) patent 8426 of Aug. 5, 1909, of the Allgemeine Elek. Ges. in the Lond. *Elec. Eng'ing*, of Aug. 12. The treated air, some 2 to 4 per cent of NO, after being passed through the oxidation chambers where the NO is converted to NO_2, is passed through apparatus containing weak basic oxides of zinc, copper, or lead. When all the oxides of nitrogen are absorbed, the salts are slowly heated in iron retorts to a temperature of 500 deg. C. The oxides are given off in the form of pure peroxide of nitrogen which is then converted in water towers to 40 per cent commercial acid, or condensed as peroxide of nitrogen. If the heating of the salts is performed in a vacuum, a much lower temperature is required.

Evaporators.—"Castings for the Sugar Industry and the Chemical Trades" is the title of a booklet treating of vacuum pans, multiple effect evaporators, distillers, defecators, rosin stills, soda kettles and similar apparatus, together with surface, jet and barometric condensers, wet and dry vacuum pumps, cooling towers, centrifugal pumps, and other vacuum apparatus manufactured by the Wheeler Condenser & Engineering Company, of Carteret, N. J. The booklet is quite handsomely illustrated.

A New Aluminium Syndicate.—According to the London *Electrical Review* of July 30, the first practical step in connection with the proposed revival of the international aluminium syndicate has been taken, by the arrival at a complete agreement of the representatives of the French producers at a conference held in Paris on July 19. It is now intended to approach the Aluminium Industry Company of Neuhausen with the object of coming to a fresh understanding, which, if concluded, will probably foreshadow the re-establishment of the syndicate. The Paris conference was the second of the kind. The announcement of the first conference has already led to considerable dealings, on the one hand, in the shares of the Swiss company at Zurich, which advanced by 10 per cent in the four days ending with July 16, while a further rise is mentioned in a report from Manheim to the effect that the German merchants have just raised the price of aluminium by 1 to 1¼ cents to 16 cents per pound. It is not known for the moment whether the French companies have yet made any advance in the price of the metal, but it is understood that the demand has grown in recent months, whereas a sudden decline took place in 1907 and continued during 1908, although it has to be borne in mind that the productive capacity of various countries has been largely increased in the past two years. The stocks of the two French companies are reported to have been cleared, and apparent confirmation of the expansion in requirements is shown by the circumstance that the exports of aluminium from France in the first five months of this year amounted to 617 tons, as compared with only 126 tons in the equivalent period in 1908.

Digest of U. S. Patents

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

ELECTRIC FURNACES (*Continued*).

618,391, Jan. 31, 1899, Hugues Bovy, of Geneva, Switzerland.

Resistance type. Designed for production of calcium carbide. The furnace comprises an open-topped upper casing insulated by bricks from a lower casing filled with a layer of subdivided carbon on which rests a series of carbon blocks separated by carbon powder held in place by carbon plates. Over each block is an electrode, these upper electrodes being surrounded by the material to be treated. Direct, or monophase or polyphase alternating electric current may be used, the current passing through the upper electrodes to the carbon blocks, which become incandescent. The vapors produced at these points of maximum heat pass upward through the molten material, stir it and distribute the heat.

618,703, Jan. 31, 1899, Hiram Stevens Maxim, of London, England.

Arc type. Designed for manufacture of "diamond carbon." The furnace consists of a strong steel shell lined with bricks of compressed silica or magnesia. Carbon electrodes secured to water-cooled holders pass through strong upper and lower heads. The furnace may have an interior water-cooled lining. The upper electrode is adjustable and the upper head may be formed with interrupted screw threads. A hydrocarbon, such as gasolene, and carbon dioxide in a solid or snow-like condition is placed in the furnace. The carbonic dioxide is, by the heat of the arc converted into carbon monoxide, thereby creating very high pressure. The carbon in immediate contact with electrodes is converted into "diamond scales," which have high electrical resistance, and may be used to, when powdered and mixed with tar, pitch or sugar, be molded into lamp filaments. Furnace may be used for any purpose requiring high temperatures and pressures.

625,252, May 16, 1899, Hilliary Eldridge, Daniel Johnson Clark, and Sylvain Blum, of Galveston, Tex.

Arc type. Designed for production of calcium carbide and illuminating gas. Fire-brick structure with open-topped furnace chamber in upper portion. The sectional cathode of metal is located in bottom of chamber. A counterweighted fume-collecting hood is mounted over furnace, the counterweighted anode depending therethrough and insulated therefrom. A rotatable plate carrying a stirrer or plow is mounted on ball bearings on the upper rim of the furnace. Two annular concentric pipe coils, the outer one for air, and the inner for gas, surround the charge. The heat of the arc reduces material; the heated air is conducted to a carburetor; and the gas is fixed in the inner coil.

625,918, May 30, 1899, Ernest Bailey, George Reeve Cox, and Walter Thomas Hey, of York, England.

Arc type. Designed for production of white lead. A closed pot for melting lead is mounted over a furnace. Depending through the pot cover is a perforated adjustable carbon electrode, mounted in an insulated bridge. Through a pipe passing through the electrode is supplied a mixture of steam, carbonic acid, and acetic acid vapors, which is projected against the molten lead and combines with the lead volatilized by the arc to form white lead, which is collected in flannel bags. The melting pot is the positive pole of the circuit.

628,373, July 4, 1899, Frank P. Van Denbergh, of Buffalo, N. Y.

Arc type. Designed for reduction of ores, typical processes being production of phosphoric acid from apatite, sulphuric acid from gypsum, reduction of cinnabar ores or alkaline chlorides and bromides. The closed furnace of refractory material has a lower portion, for containing fused material, of less diameter than upper chamber, through whose side walls project longitudinally adjustable electrodes carried in and insulated from swiveled or ball and socket bearings, made gas tight. The charge is fed through the roof by a mechanical feeder, from a double-valved hopper, into the arc. Gases escape through a pipe to a condensing chamber. Molten material discharges continuously through an upwardly extending duct in the wall of the furnace, so that level of molten material in the crucible is maintained constant. The bottom of the crucible is removable.

NEW BOOKS.

Rose, T. Kirke. The precious metals; comprising gold, silver and platinum. 311 pages, illustrated. Cloth, $2 net. New York: D. Van Nostrand Company.

Metal Corrosion and Protection. (A very full reference list of books, articles and papers on this subject, with a brief note on the contents of each article, etc.) 64 pages. 10 cents. Pittsburgh: Carnegie Library.

Groth, L. A. Welding and cutting of metals by aid of gases or electricity. 280 pages, illustrated. Cloth, $3 net. New York: D. Van Nostrand Company.

Holley, Clifford Dyer. The lead and zinc pigments. 359 pages. Cloth, $3 net. New York: John Wiley & Sons.

Kemble, W., Fritz and Underhill, C. Reginald. The periodic law and the hydrogen spectrum. 16 p. fold. diagrs. Cloth, 50 cents. New York: D. Van Nostrand Company.

Crane, Walter R. Index of mining engineering literature; comprising an index of mining, metallurgical, civil, mechanical, electrical and chemical engineering subjects as related to mining engineering. 824 pages. Cloth, $4 net. Mor., $5 net. New York: John Wiley & Sons.

Tracy, J. Clayton. Exercises in surveying for field work and office work; with questions for discussion; intended for use in connection with the author's book, "Plane Surveying." 183 pages. Cloth, $1 net. New York: John Wiley & Sons.

Clerk, Dugald. The gas, petrol and oil engine, v. 1. General principles of the internal-combustion engine, together with historical sketch. New ed. revised and enlarged. 369 pages. Cloth, $4 net. New York: John Wiley & Sons.

Houghton, C. Edwin. The elements of mechanics of materials; a text for students in engineering courses. 194 pages, illustrated. Cloth, $4.50 net. New York: D. Van Nostrand Company.

BOOK REVIEWS.

Through the Yukon and Alaska. By T. A. Rickard. 392 pages, 175 illustrations, indexed. Price, $2.50. San Francisco: Mining & Scientific Press.

Another book of the "new kind" inaugurated by T. A. Rickard, a "mining and metallurgical journey" up to date. The title page is in imitation script, the first chapter a series of paragraph sketches about the Inland Sea in artistic prose; the second chapter a picturesque statement of the history of the country and its development as related to its topography, and so on throughout the book skillful word painting is linked with scientific observations in a truly original and most effective manner.

A particular feature of high value and withal extremely attractive is the striking and beautiful illustrations, many of them worth looking at more than twice. The combination of fine description, splendid photographs, and accurate information—geographic, mining, metallurgic, and economic—makes altogether a notable book to be highly recommended to so many classes of people that we might as well say right at once—to everybody.

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Die Electrochemischen Verfahren der chemischen Gross-Industrie. Vol. 1. Electrometallurgy of aqueous solutions. By Dr. Jean Billiter, privatdocent at the University of Vienna. 284 pages, 117 illustrations, no index. Price, 12 marks. (Retail price in New York, $4). Halle a. S., Wilhelm Knapp.

This is the first volume of an ambitious work, the four volumes of which are to be: Electrometallurgy of aqueous solutions, electrolysis of aqueous solutions with insoluble anodes, electrolysis of molten salts, and electric furnaces. The object is to give a description of the present status of these industries, discussing along with the description the scientific and technical principles involved in the operations.

The introduction presumes to give a short account of modern electrochemical principles and theory. The presumption is false, for the author literally does not know what he presumes to be talking about. He wofully misstates Faraday's law, confounding gram-equivalents with gram-ions, and chemical equivalents with atomic weights and with electrochemical equivalents. All users of this book are advised to skip this chapter and to get their fundamental electrochemical theory and principles from other and more trustworthy sources.

The book describes and discusses the electrolytic refining of copper, silver, gold, lead, zinc, tin, nickel, bismuth and cadmium. The attempt to apply the formulas of ionic concentration, etc., to practical data results in many misfits, practical *impasses*, and very few illuminating explanations. The descriptions of industrial processes are good and fairly well illustrated. They offer, however, little of value not to be found in other existing treatises.

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Annuario della Industria Mineraria, Metallurgica e Chimica Italiana. Second year, 1909. Duodecimo, 580 pages. Price, 10 lire. (Retail price in New York, $2.65.) Turin: G. U. Cassone.

An annual with characteristics different from those in German, French or English. Over half the book is filled with the existing laws, rules and regulations affecting the mining, metallurgical and chemical industries in the various provinces of Italy. The second section concerns the government bureaus, schools and scientific societies controlling or active in these industries. This is supplemented with a very well compiled list, with addresses, of some 1600 prominent Italians in these lines; also obituary notices for 1909 (including the well-known Vincenzo Spirek). The section following gives a list of all the mines in Italy, classified according to the ores worked, and giving names of the operating companies. The concluding chapter has miscellaneous tables, rather desultory in content, and gives the Italian production of ores, metals and chemical products for 1906 and 1907.

We have noted in the above review the information contained in the book most likely to make it valuable to the reader outside of Italy.

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Elementary Chemistry. By F. B. Emery, A. M., McKinley High School, St. Louis, Mo. 666 pages, 191 illustrations, 36-page index. Price, $1.50. Easton, Pa.: The Chemical Publishing Company.

A marvellously cheap book, from the printer's and publisher's standpoint, and a rattling good chemistry for the beginner to start on. It has many novel features, but it has all the old-fashioned virtues. The author is sound in his principles and has worked them out successfully.

It is many years since the reviewer has seen a book on elementary chemistry which he would recommend as warmly and as unreservedly as this one.